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EDITOR

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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THE LONG BEACH OIL FIELD AND ITS PROBLEMS[1]

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Los Angeles, California

LOCATION

The Long Beach field is located at the north city limits of the city of Long Beach in the southern part of the Los Angeles Basin, and about 2 miles from the coast.

A map of the Los Angeles Basin shows a number of hills which lie along a line striking about N. 42° W. These hills extend from the San Joaquin Hills in the southeast to and including the Cienega (Baldwin) Hills on the northwest. Their elevations range from about 60 feet above sea level to 517 feet in the Cienega Hills. Low river valleys or mud-filled estuaries lie between the hills. Along this line, about midway between the San Joaquin Hills and the Cienega Hills, rise two domelike hills whose summits lie about 1 mile apart. The higher of these—Signal Hill—has an elevation of 364 feet; the lower, Reservoir Hill, 213 feet. A well-marked terrace borders the northwest side of Signal Hill. These two hills, with the terrace, are the surface expressions of the subsurface structure upon which the Long Beach oil field is situated.

PREVIOUS KNOWLEDGE OF STRUCTURE

The existence of the structure at Signal Hill had been known for a great many years, for the dips in the San Pedro formation

[1] Read before the Association, at the Los Angeles meeting, September 20, 1923. Manuscript received by the Editor, February 6, 1924. Published by permission of Mr. G. Legh-Jones, president of the Shell Company of California.

exposed on the hill indicate a closed anticline. These surface dips indicated that the structure was not very large and that it terminated abruptly in a steep plunge at the northwest end. This was very misleading and led to the belief that the pool ended at what has since been proved to be the center of the productive area and the richest part of the pool.

The question naturally arises, why, if the structure were known, had it not been tested before. There were several good reasons for this. In the first place operators were much less numerous in California three or four years ago. As a consequence, competition was not so keen as it is today, and wildcatters were less venturesome. A few years ago the operator hesitated to drill except on some positive and visible evidence of the existence of most of the prerequisites for an oil pool, while today we see wells going down wherever there is a topographic suggestion of a fold, or where theoretical considerations indicate that there might be a fold, not to mention the wildcats that are being drilled in an entirely haphazard way.

Development along the central uplift was delayed also by incomplete knowledge of the coastal geologic section. Prior to the discovery of the Huntington Beach field, which was the first field to be discovered in the southern part of the basin, it was not known, for instance, how well represented was the Fernando formation, which is the principal oil-bearing formation of the older fields of the northern part of the basin. In the major uplifts, the San Joaquin Hills and the Palos Verdes Hills, this formation is not well exposed in outcrop, and along the central uplift it is entirely masked by the San Pedro formation and recent marine terrace deposits. As a result, many uncertainties existed as to its true character, thickness, the presence of adequate reservoir sands, and the possibilities of the Fernando as an original source of oil. The thickness of the overlying San Pedro formation also being unknown, it was not certain that the oil, even if it existed, would be within economical drilling depth.

Previous tests at different points along the central uplift also tended to discourage further exploration. On Dominguez Hill, near the present Compton field, and on the Cienega (Baldwin)

Hills near Inglewood, both located on the central uplift and to the northwest of Signal Hill, deep tests had been drilled to over 5,000 feet. Furthermore, in 1916 one of the large companies abandoned as a dry hole at a depth of 3,449 feet, a well drilled in the northwest part of the Long Beach area near the edge of the present pool. Although this well was not favorably located with respect to structure, it had a tendency to condemn the area. It was not until the Huntington Beach field was discovered in March, 1920, that interest was revived in the possibilities of the coastal uplift.

SURFACE GEOLOGY

Stratigraphy.—The surface rocks exposed in cuts on Signal Hill are loosely consolidated sand and gravel, and some clay. The deposits are of shallow water marine origin and contain beds with abundant fossil shells, which show them to be San Pedro (Pleistocene) in age. The minerals making up the deposits indicate their derivation from a quartz diorite area which lay probably to the north.

Structure.—The San Pedro beds in Signal Hill have been steeply folded, some of them dipping as much as 35°. Strike and dip readings show further that the domelike shape of Signal Hill is really due to the rock structure, and that, except on the northwest side, it has been but little affected by erosion. The structure as indicated by the surface beds is a fold plunging rather steeply toward the northwest and less steeply toward the southeast. As will be seen later, however, this apparent plunging is the reverse of the condition found below the surface, though the axes of the surface and subsurface structures in general coincide. Small faults occur in the San Pedro beds along the south side of Signal Hill. The steep south slope of the Hill has been generally thought to be due to faulting, but up to the present time no conclusive evidence has been found to prove the existence of an important fault.

SUBSURFACE GEOLOGY

Stratigraphy.—The rocks penetrated in drilling are of Pleistocene, Pliocene, and in some wells, possibly of Miocene age. The generalized geologic column (Fig. 1) shows the formations and their

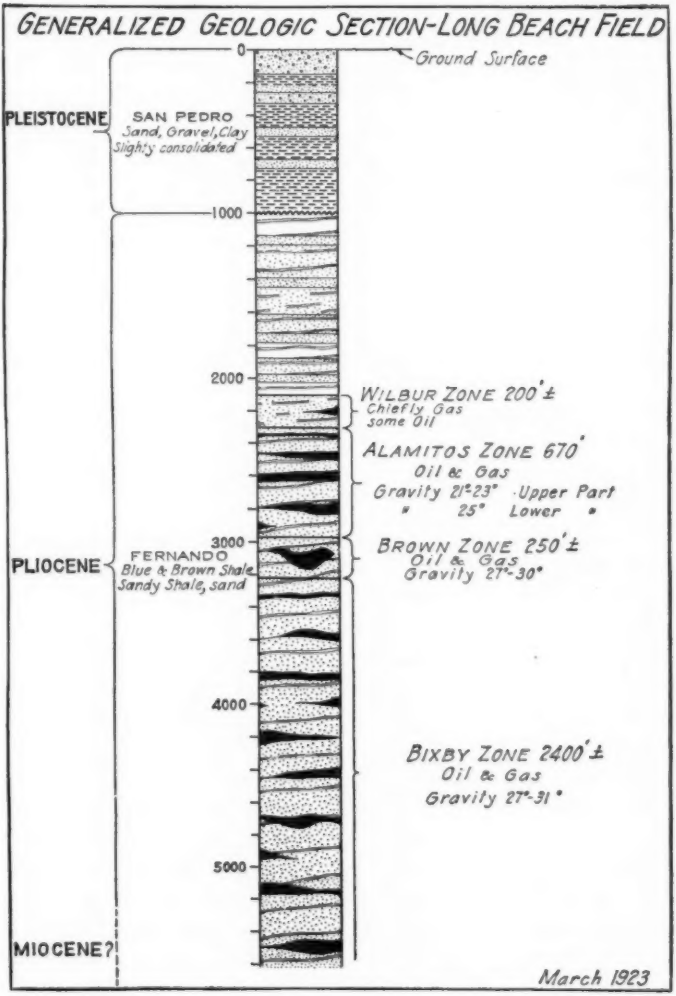

GENERALIZED GEOLOGIC SECTION-LONG BEACH FIELD
0
Ground Surface
PLEISTOCENE
SAN PEDRO
Sand, Gravel, Clay
Slightly consolidated
1000
2000
WILBUR ZONE 200'±
Chiefly Gas
some Oil
ALAMITOS ZONE 670'
Oil & Gas
Gravity 21°-23° Upper Part
" 25° Lower "
3000
PLIOCENE
FERNANDO
Blue & Brown Shale
Sandy Shale, sand
BROWN ZONE 250'±
Oil & Gas
Gravity 27°-30°
4000
BIXBY ZONE 2400'±
Oil & Gas
Gravity 27°-31°
5000
MIOCENE?
March 1923

FIG. 1

approximate thickness. The formations cannot be sharply separated from one another on evidence furnished by drill cuttings, although fossil shells which are obtained from time to time, have given us the information on which to base their age. The great homogeneity of the material encountered, together with the absence of definite marker beds, leaves many gaps in our knowledge of the underground stratigraphy. The difficulty can be appreciated when it is realized that the thickness of the Pliocene and Pleistocene beds on the north side of the Los Angeles Basin reaches possibly 8,000 feet.

The first thousand feet of a well consists largely of sand and gravel, which must be cased off to prevent caving. Sea shells are rather abundant in this material, but cuttings show little or no microscopic animal life. These beds are generally referred to the San Pedro formation, but they cannot be separated by any definite line from the strata of the underlying Fernando group (Pliocene). An unconformity probably separates the San Pedro and Fernando.

Below 1,000 feet the beds are more consolidated and consist of sand, sandy shale, and shale. For several hundred feet below the base of the San Pedro formation the shales are normally bluish-gray, and below these, brownish-gray in color. No sharp line can be drawn, however, based on this color change, and hence the top of the brown shale cannot serve as a definite horizon marker to be used in close correlations. Marine fossils have been obtained from well cuttings which show that these lower beds are probably of Pliocene age. The mineralogical composition of the Fernando indicates a source similar to that from which the San Pedro was derived. The general fineness of the sand as compared with that in the San Pedro and the relative abundance of shale points to deposition in water deeper than the San Pedro. The shales are largely organic, and many of them consist of a mass of foraminifera shells. Pieces of carbonized wood are found in many samples. The Fernando group is probably divided into two formations by an unconformity. Its thickness in Signal Hill seems to be at least 4,000 feet.

Some of the deepest wells in the field have entered a formation different from the Fernando in appearance of the shale, and yet

not typical Monterey shale (Miocene). This shale is hard, nearly black, and shows bedding planes dipping more steeply than those of the Fernando. An unconformity between the known Fernando and these beds is indicated by the fact that they are not encountered at the expected depths in some of the deepest wells. Their age may be upper Miocene, and possibly equivalent to the upper Puente shale of Arnold.

Structure.—The subsurface structure of the Signal Hill oil field is that of an elongated dome which plunges rather steeply southeast and rather gently northwest. The proved area of the dome is about 3 miles long by $\frac{3}{4}$ mile wide, the surface area being about 1,200 acres. The closure on the structure is about 1,200 feet.

The subsurface contour map, Plate VI, gives the approximate depth of the top of the Alamitos oil zone. The contour interval used is 100 feet and the datum plane is sea-level. The elevations of the wells range from a little less than 100 feet to a little more than 350 feet. The construction of the contour map cannot be discussed here, but it must be pointed out that the absence of marker beds introduces considerable uncertainty with regard to the location of the contour lines near the edges of the field.

OIL ZONES

The separation of the productive oil measures in the Signal Hill field into distinct zones is not easy in view of the absence of certain means of correlation and differentiation. Most of our information on which to base a division of the productive measures into different zones was obtained in the early days of the field, when the sands were being tested. After it was found possible to produce from 2,000 or more feet of sand free from water, the divisions into zones did not seem so vital. As water encroaches, however, it will become necessary to divide our present zones into a great many more units. The characteristics of the oil zones as used by the Shell Company at the present time will be described briefly (Figs. 1, 2, and 3).

Wilbur zone.—The highest of the oil measures, the Wilbur zone, is generally passed up near the apex of the structure because of heavy gas pressure, and around the edges of the structure because

City of Long Beach (Shell)
PET. MID.
SHELL CO (Burgess)
AVE.
AVE.
AVE.
AVE.
AVE.
SPRING
ST.
A.T. Jergins (Municipal)
ANDERSON
ST.
PET. MID.
SHELL CO (Cresson)
GEN. PET. K.B.H.
SHELL CO (Abercellus)
ATLANTIC
CALIFORNIA
ORANGE
WALNUT
CHERRY
WILLOW
ST.
UNITED OIL
GEN. PET.
SHELL (Dobyns)
(Andrews)
2400
(Horsch)
UNION OIL
Stratton
(Fee)
SHELL Cherry Hill
(Wilbur Com)
SHELL
(Babb & Tucker)
2790
2800
HILL
ST.
2900
3000
3100
3200
3300
B
1

MAP OF
LONG BEACH OIL FIELD
LOS ANGELES COUNTY
CALIFORNIA

SHOWING
SUBSURFACE CONTOURS OF TOP OF ALAMITOS ZONE

SCALE
FEET

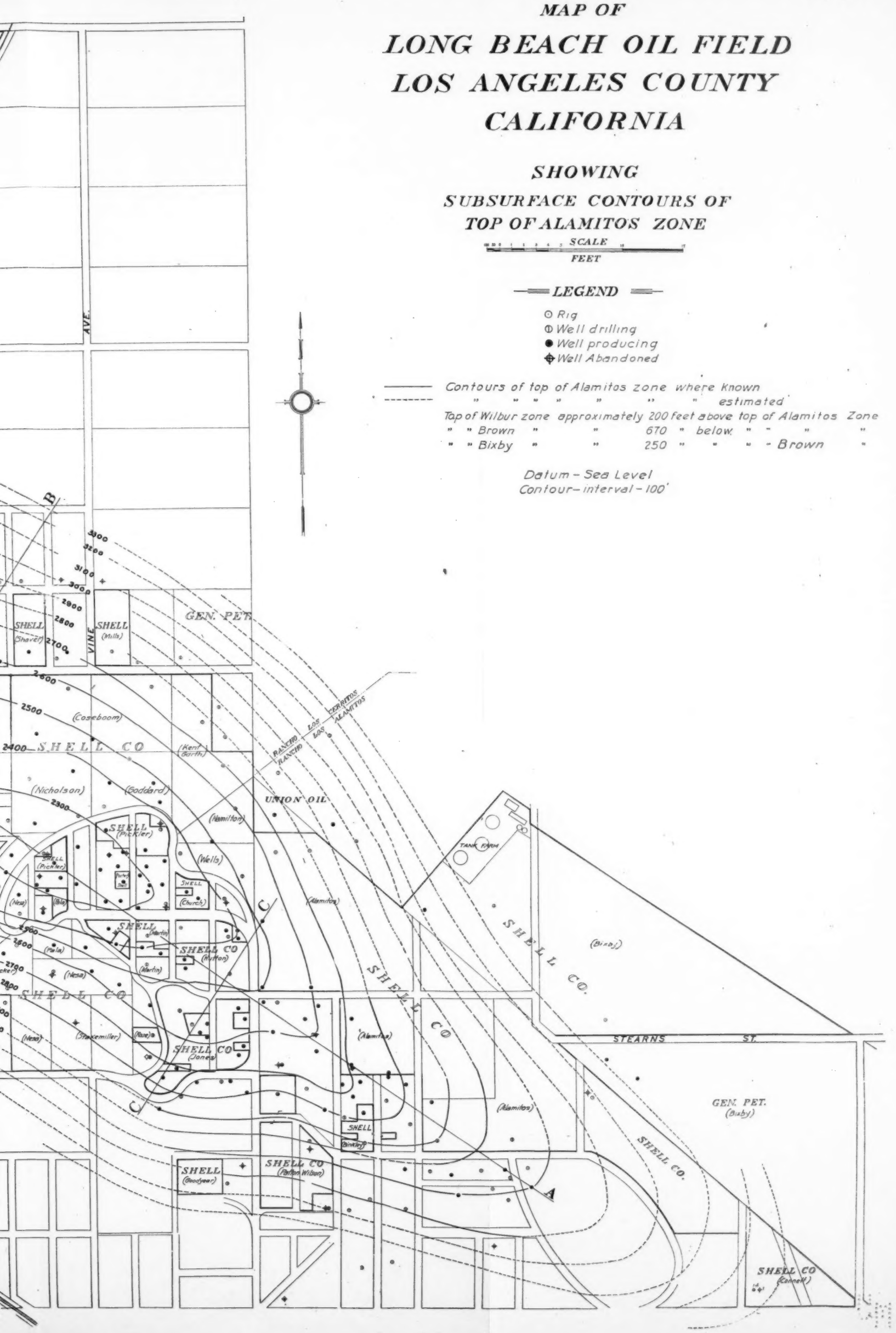
LEGEND

- ⊙ Rig
- ◐ Well drilling
- ● Well producing
- ⊕ Well Abandoned

——— Contours of top of Alamitos zone where known
- - - - - - - " " " " " " " estimated

Top of Wilbur zone approximately 200 feet above top of Alamitos Zone
" " Brown " " 670 " below " " " "
" " Bixby " " 250 " " " - Brown "

Datum - Sea Level
Contour-interval - 100'



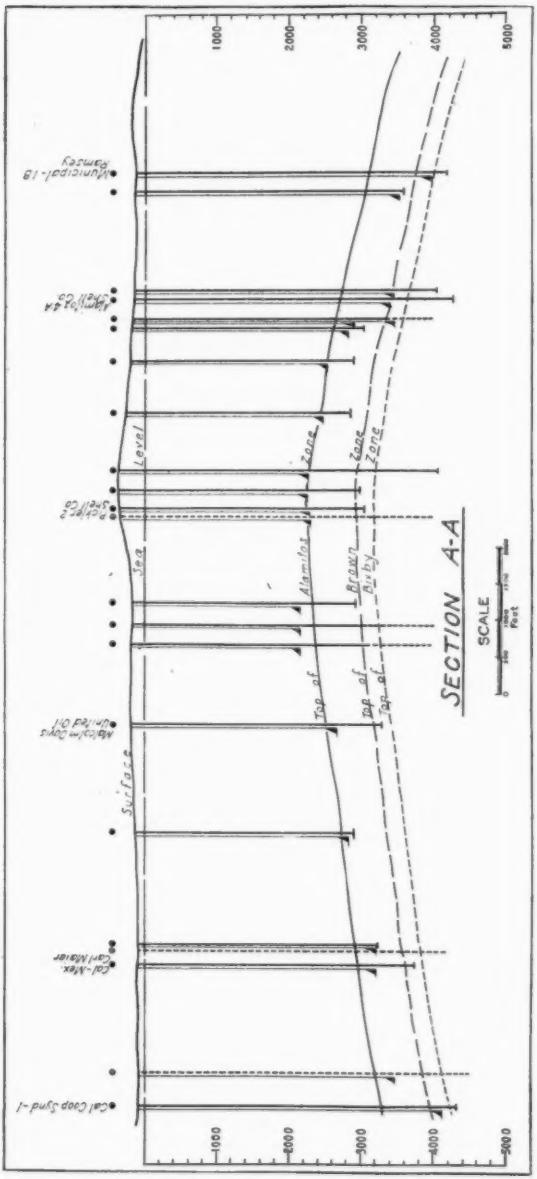

1000
2000
3000
4000
5000
Municipal-18
Ramsey
Amer. Pet. Co. 24
Pet. & Syndicate Co.
Level
Sea
Surface
Top of Ranger zone
Top of Upper Ranger zone
Top of Brown Sandy
Top of Hamilton
SECTION A-A
SCALE
Mahoney Davis United Oil
Col.-Mex. Petroleum
Cal. Coop Synd.-1
1000
2000
3000
4000
5000

FIG. 2

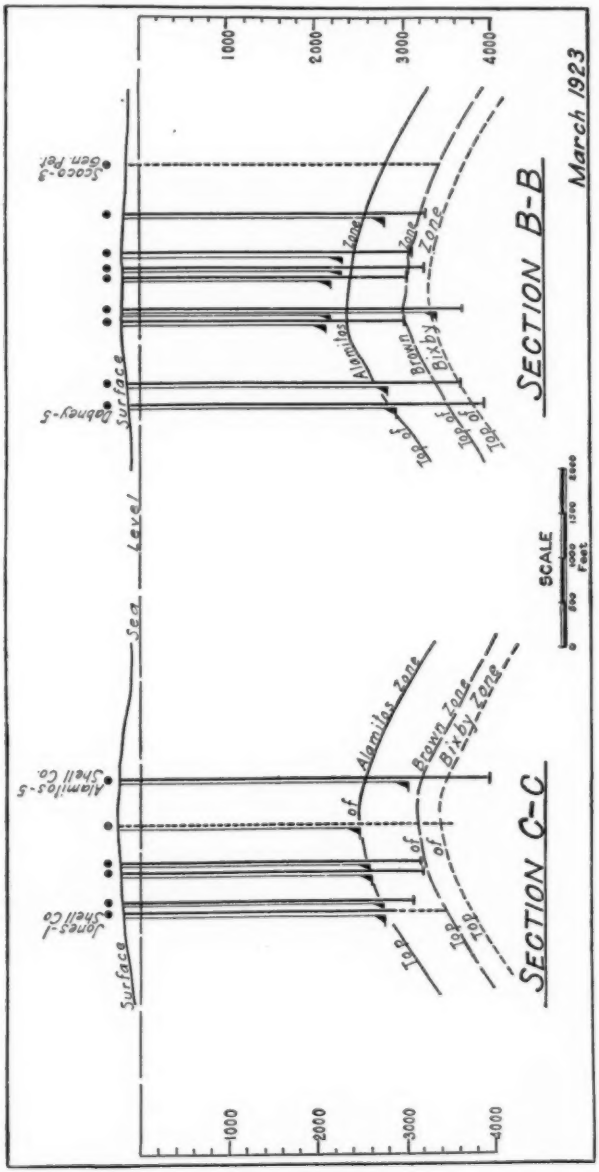

SECTION B-B
March 1923
SECTION C-C
SCALE
Feet
Sea Level
Surface
Alamitos zone
Brown zone
Bixby zone
Top of
Goheny-5
Alamitos-5
Shell Co.
Jones-1
Shell Co
Scco.-3
Gen Pet.
1000
2000
3000
4000

FIG. 3

of water. With the exception of Shell Company Wilbur No. 1, which produced about 50 barrels per day, no wells have attempted to produce from the Wilbur zone alone, but its limited lateral extent would indicate a small production. Near the apex of the structure disastrous gas blowouts have occurred in this zone. A number of wells west of Cherry Avenue have, however, been cemented above or in the Wilbur zone. The thickness of this zone is probably not over 200 feet.

Alamitos zone.—The Alamitos zone takes its name from the discovery well, Alamitos No. 1. Most of the early wells, which produced from the upper part of this zone, gave oil with a gravity of 21° to 23°. Later wells, going a little deeper than 400 feet into the Alamitos zone, came in with a higher production and yielded oil of higher gravity than the shallower wells. Still other wells, in the eastern part of the field and farther down on the structure, encountered water at approximately 400 feet from the top of the Alamitos zone. The San Martinez Booth No. 1 is believed to have entered this lower zone first; hence this was called the Booth zone. The gravity of the oil from the Booth zone was about 26°. No lithologic division, such as a thick body of shale, could be found that might be used as a marker between the Alamitos zone and the Booth zone, so the two zones could only be differentiated on gravity of the oil. Since later wells were drilled to produce from several zones, it no longer became possible to recognize the Booth zone by increase in gravity. It has, therefore, been included with the Alamitos. The thickness of the Booth zone appears to be about 270 feet and the total thickness, then, for the Alamitos zone as used in the sections is approximately 670 feet.

Brown zone.—Wells near the apex of the structure which were drilled more than 670 feet below the top of the Alamitos zone produced oil in greater amount and of still higher gravity than those drilled only into the Alamitos zone. Oil from some of the wells showed a gravity of 30°. This higher gravity zone was called the Brown zone, from the fact that the Petroleum Midway Brown No. 1 is thought to be the discovery well of this zone. Again, no definite lithologic marker can be recognized in the logs for delimiting this zone. Although the top of the Brown zone is fairly well defined

near the apex of the structure, at the edges of the field it is largely conjectural. Gravity differences cannot be relied upon around the edges of the structure, because the gravity seems to become lower as one goes down the dip.

Bixby zone.—In the eastern part of the field a sand carrying a heavy flow of hot salt water is followed by a rather rich oil sand, about 250 feet below the top of the Brown zone. The Shell Bixby No. 1 well has been producing from this sand, and it is therefore called the Bixby sand.

PRODUCTION PROBLEMS

Water.—Water in the Long Beach field has not yet become serious except around the edges of the structure, but with the advance of the water toward the higher parts of the structure, and its appearance in wells now producing clean oil, the question as to its location will become acute. The location of the water in many of the wells will be difficult, if not impossible, due to rather abrupt and irregular changes in the lithology of the beds, which fact will cause the water to advance farther and more rapidly along the coarser sand beds at different horizons than along the finer ones; and also due to the large amount of open pipe in the holes.

Drilling.—The first few wells in the Long Beach field were drilled to the cementing point with rotary and then finished with cable tools. With the exception of these wells, all the drilling since has been by the rotary method. The time taken to drill the wells entirely with rotary tools is only about one-fourth the time necessary to drill to the cementing point with rotary and then to finish with cable tools. With rotary it has been possible to finish a well for production to a depth of 5,500 feet in approximately 120 days. The time factor, where the primary object is to get the oil as quickly as possible in fields where competition is strong, is proving the rotary system to be the big economic factor. Besides the saving in recoverable oil, in a field where the sands are fast being drained by competitors, there is the material decrease in drilling expense.

The formations are very effectively drilled by the rotary system, being consolidated just enough to stand up well after they are mudded. After casing off the upper 600 to 1,000 feet of loosely consolidated sand and gravel, the holes are almost entirely free

from caving sands. The advantages of the rotary system over cable tools are evident when it is considered that it has become common practice in the field to finish wells 1,800 to 2,500 feet below the lowest shut-off point. This necessitates the setting of an oil string with 1,000 to 2,500 feet of friction. With cable tools it is not practicable in this field to have more than about 400 feet of friction on the casing; consequently, the hole would have been greatly reduced in size by the time the full depth of the oil measures were opened. Within a limited area on the crest of the structure, productive oil measures free from water have been penetrated for a thickness of 3,150 feet, or 5,450 feet below the surface. This would require seven or eight strings of casing below the water string, which is impossible when drilling with cable tools. Cable tool drilling to great depths also means a great waste of casing, as the various drilling strings serve no useful purpose after the hole is finished.

Mudding.—Little or no trouble is had from caving sands after the upper loose formations have been cased off. It has been found by experience that the condition or consistency of the mud fluid has a great deal to do with successful rotary drilling. Experiments have shown that the depth of penetration of a light gravity mud fluid into a porous formation is greater than that of a heavier gravity. It has been learned that in general practice mud of a specific gravity of 1.13 gives the best results. Where the hole has been drilled with a mud fluid of this gravity it has been found that the mud wall of the hole is more permanent and that the sand carried in suspension in the mud fluid settles out in the settling troughs much faster than when mud fluid of heavier gravity is used. For a fishing job in deep drilling, the use of the lighter gravity mud fluid may sometimes prove to be a disadvantage, for the sand held in suspension in the mud fluid in the hole may settle around the fish, very often freezing it before it is possible to get back into the hole with fishing tools. Experiments are now being made to find a mud fluid of the proper specific gravity which will hold the sands in suspension a little longer and overcome this difficulty.

Circulating oil.—In fishing jobs where it has been found that the drill pipe has been frozen by formation settling around the fish,

it can often be successfully loosened by circulating oil. Circulating oil causes the formations to creep and, in cases where sand has settled around the fish, the oil tends to hold it in suspension and causes it to ooze. By keeping a tension on the drill pipe and then circulating oil around the frozen fish, it usually comes loose very easily.

Casing.—The casing program adopted for the wells in the field has been such as to meet the local conditions in the different parts of the field. The conductor casing is cemented at depths ranging from 600 to 1,000 feet. This string cases off the loose surface formations and also allows the water string to be anchored, which procedure is often a safeguard against blowouts from behind the water string.

The depths at which water strings are cemented range from 2,300 to 4,000 feet or more in different parts of the field, depending upon the structural location of the well and the water conditions. The larger-sized casings are popular in the field. It has been found advantageous to maintain the largest-sized hole possible so that the well is in condition to be deepened if desired. This also facilitates additional water shut-off if water should encroach upon the well.

Because of the great amount of friction on long strings, it is the general practice in the field, after setting one string, to omit the next succeeding size and set the next smaller size, that is, if 10-inch casing is used for the water string, to use $6\frac{1}{4}$-inch casing for the oil string.

The oil string is landed with screen pipe on the bottom, usually extending to the shoe of the water string and open to the full thickness of the productive oil measures. Sometimes when the upper measures are lean, it is best to case these off behind blank casing. There is considerable variation in the richness of the different sands within the productive horizon, and where, by means of a series of production tests as the well is carried down, the relatively rich and lean sands have been located, it has been found that by blanking off the lean portions, wells will give as good a yield as if the whole zone were open.

In present-day deep drilling, the casing program is planned so that as much as possible of the drilling is within a protective casing.

The usual program is to set 18-inch for the conductor, 11-inch for the water string, land $8\frac{1}{4}$-inch for an oil string at maximum depths of 3,500 to 4,000 feet, and then complete the well with a $5\frac{3}{16}$-inch liner.

A 27-inch diameter hole is drilled for the 18-inch conductor casing. After cementing this string, a 17-inch hole is drilled to the cementing point of the 11-inch water string. The hole is then reduced to $10\frac{5}{8}$ inches in diameter, which size is carried to the landing-point of the $8\frac{1}{4}$-inch casing. After setting this string, a $7\frac{5}{8}$-inch hole is drilled to the completion depth for the $5\frac{3}{16}$-inch liner. Six-inch drill pipe is used in drilling the hole to the cementing-point of the water string. After the water string is set the 6-inch drill pipe is broken down and replaced with 4-inch drill pipe, which is used in 11- and 10-inch casings. To drill in through $8\frac{1}{4}$- and $6\frac{1}{4}$-inch casing, 3-inch drill pipe is customarily used. In adapting the drill pipe to the size of casing in this manner, it is easier to recover in the event of a fishing job.

Cementing.—As so many of the improvements in modern deep-well drilling have as their principal objective the attainment of additional speed, so also with the cementing for water shut-off. This improvement consists of the perfection of a chemical reagent which, when used with a good grade of oil-well cement, speeds up the hardening or hydration of the cement and reduces the normal time for the cement to set from fourteen to four days. In addition to the time saved, it has been found also that the use of the reagent increases the percentage of successful jobs.

For placing the cement, the Perkins method is used for cementing the conductor casing and the water string. The usual amount of cement used is 300 sacks, both for the conductor string and the water string. This is sufficient to provide a good anchorage for the conductor string and also to extend far enough above the shoe of the water string to afford protection to the upper oil and gas formations which it is desired to pass up.

Coring.—The taking of cores for geologic information has become common practice in California rotary drilling. This overcomes the chief objection of the geologist to the use of rotary in exploration. In the development of proved fields as well, coring has become almost universal. It enables the geologist to have a look at the

undisturbed formation whenever desired. This enables him to locate definitely the top of the oil zone and to select a suitable bed in which to cement.

Progressive production tests.—To supplement the information gained from cores, the method of making progressive production tests is commonly used. This is done by running in a string of tubing, with a joint or two of perforated pipe on the bottom at any stage of the drilling. A swab or bailer is then run for production. In this way the relative richness of different parts of the oil horizon can be determined and any water that may be present can be located definitely.

HISTORY OF DEVELOPMENT

The history of the development of the Long Beach field is interesting as exemplifying the intensity and speed of development of the new fields of the Los Angeles Basin. The discovery well of the field, Alamitos No. 1, on the lease of the Alamitos Land Company, was brought in by the Shell Company, June 25, 1921. The well was completed at a depth of 3,114 feet, and gave an initial production of 500 barrels of 21 gravity oil.

The discovery immediately caused great activity in leasing, encouraged greatly by the town lot subdivisions which offered a tempting opportunity for small operators and lease speculators, many of whom had received their schooling under similar conditions in the Huntington Beach field.

The first development naturally centered in the vicinity of the discovery well and was confined mostly to the main eminence of Signal Hill. Subsequently there were several outstanding events in the history of the field that stimulated and guided development.

First, the discovery in Shell Company Horsch No. 1. This well, located ½ mile northwest of the discovery well, was finished in October, 1921. It was completed at 2,730 feet, with an initial production of 350 barrels. The significant feature of this well was that the top of the oil horizon was found almost 200 feet higher than correlations based upon the surface geology indicated. This was the first intimation that the structure in depth did not conform to the structure in the San Pedro formation at the surface, and it

showed that the pool was probably considerably larger than at first supposed.

Second, the discovery and blowout in the General Petroleum Corporation Black & Drake No. 1 in January, 1922. This well blew out and got out of control when drilled out for a cement test at 2,298 feet. Starting with a tremendous flow of gas that wrecked the derrick, it finally went to oil, flowing at an estimated rate of over 10,000 barrels a day. As this well was located only a short distance beyond previous production it did not extend the field very much, but it demonstrated the great richness of the sands along the crest of the structure. It gave a tremendous impetus to development in all parts of the field, for it encouraged operators to drill on plots that under other conditions would have been considered much too small for profitable operation.

Third, the discovery in the Cal-Mex Kirkpatrick No. 1 in August, 1922, and Herwick No. 7 in December, 1922. The Kirkpatrick No. 1 was located $\frac{3}{4}$ mile in advance of existing production, and at the time was generally considered to be much too far out for possible production. Next, the success of Herwick No. 7 extended the production for almost another half-mile. Together, these two wells almost doubled the proved area of the field and encouraged the rapid development of all the intervening territory.

Fourth, the performance of Shell Andrews No. 3. In March, 1923, while drilling at a depth of 5,050 feet, the well got beyond control and for eight hours flowed at the rate of over 30,000 barrels a day. This well, located near the center of the field, did not prove up any additional area, but it proved the great thickness of the oil measures and the great richness of the lower sands. This quieted any fears of encountering bottom water, and caused operators to carry their wells to depths that were unthought of in the earlier history of the field. The deepest well on record at the present time is the General Petroleum Clock No. 1, which is now 5,972 feet deep. The bottom of this hole is still showing oil, indicating a thickness of over 3,500 feet of oil-bearing formation.

The following figures show the speed with which the field has been developed: Six months after discovery, at the end of 1921, there were 38 operators, 75 active rigs, 50 wells completed and

drilling, 8 wells producing, 130,000 feet of hole drilled, an average daily production of 1,000 barrels and there had been produced a total of 82,000 barrels. One year later, at the end of 1922, development had grown to 158 operators, 395 active rigs, 361 wells completed and drilling, 148 wells producing, 1,160,000 feet of hole drilled, an average daily production of 100,000 barrels, and a total cumulative production of 18,100,000 barrels. At the end of August, 1923, twenty-six months after discovery, there were 222 operators, 700 active rigs, 630 wells completed and drilling, 270 wells producing, 2,600,000 feet of hole drilled, an average daily production of 240,000 barrels, and a total cumulative production of 57,700,000 barrels.

The curves (Figs. 4 and 5) show in terms of footage drilled and total cumulative production the comparative speed of development of Richfield, one of the older fields, and the three new fields, Huntington Beach, Santa Fe Springs, and Long Beach. Richfield represents a field that has been developed under more normal conditions of fewer operators, larger leases, and more lenient drilling obligations. It presents a striking contrast to the frenzied development of the newer fields under stress of keen competition occasioned by small leases and difficult lease requirements.

OVERDRILLING

As a result of this great development, the field has already been very much overdrilled. The field is only a little over two years old and already there is an average of one well to every two acres—and the end has not yet been reached, for new wells are being started almost daily.

As an example of the extremes to which the density of drilling has been carried, on one 10-acre tract there are 18 producing wells and 5 wells drilling, a total of 23 active wells, or less than a half-acre to the well. Another 10 acres has 20 active wells. On one 5-acre tract there are 11 producers and 1 well drilling, a total of 12 active wells, or a little over four-tenths of an acre to the well. On individual leases the congestion is still greater and it is not unusual to find 3 wells on one-half acre. There are instances of drilling on strips of land that were originally intended for street purposes and only 30 feet wide, or half the width of the ordinary street.

The fundamental cause of this overdrilling is, of course, the smallness of the individual property holdings. Two-thirds of the

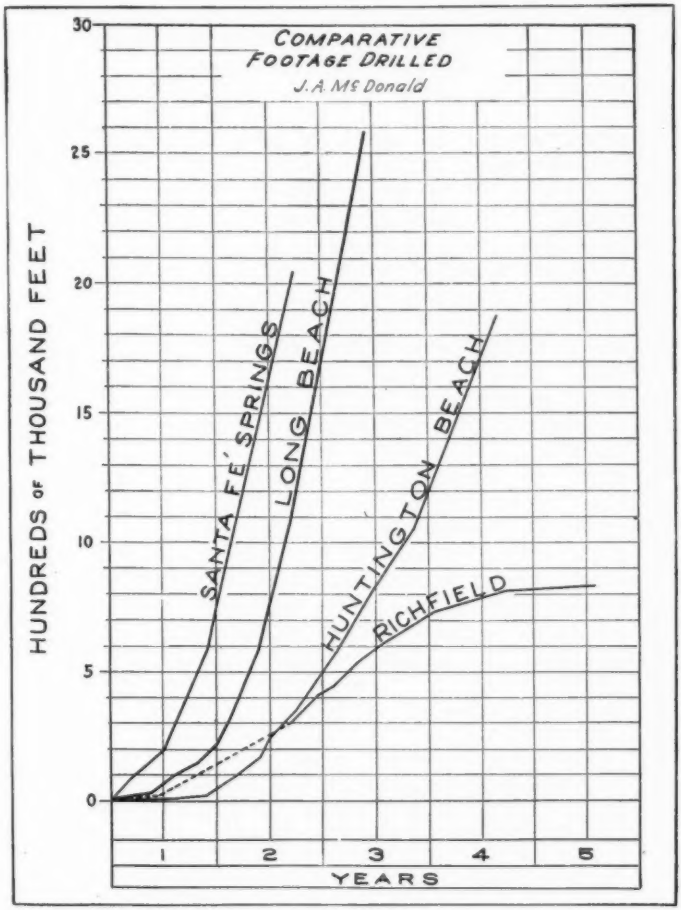


FIG. 4

Signal Hill area is subdivided into town lots, partly within the city limits of Long Beach and closely built up with homes. Outside of that, there are only a few large tracts ranging in size from 60 to

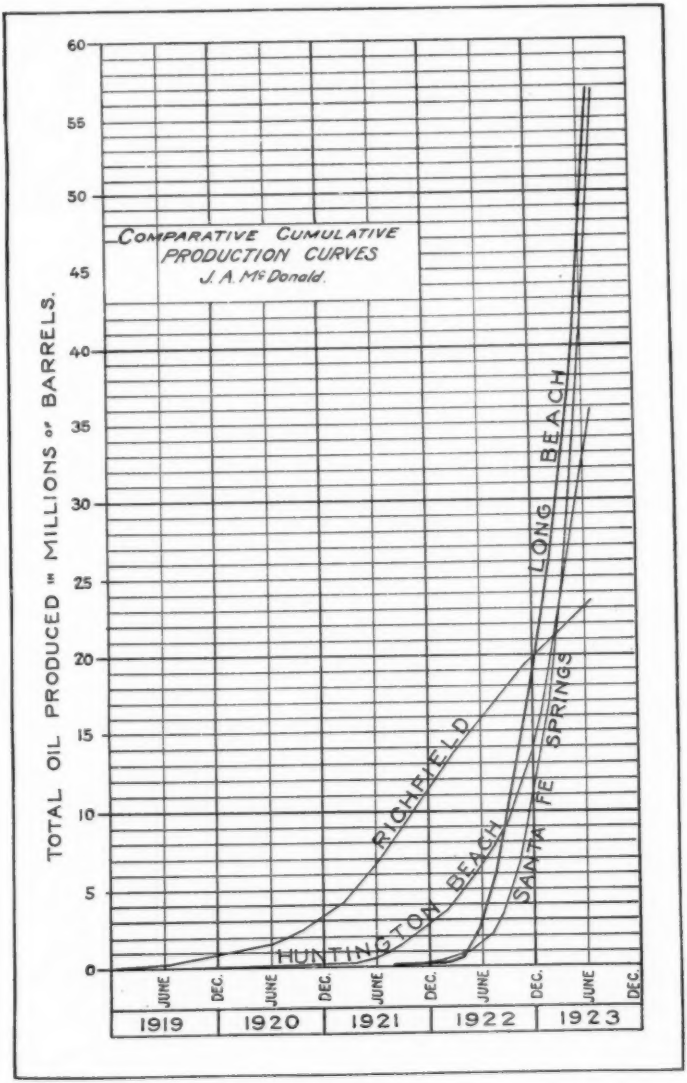

COMPARATIVE CUMULATIVE PRODUCTION CURVES
J. A. McDonald.
TOTAL OIL PRODUCED = MILLIONS of BARRELS.
60
55
50
45
40
35
30
25
20
15
10
5
0
RICHFIELD
HUNTINGTON BEACH
SANTA FE SPRINGS
LONG BEACH
JUNE
DEC.
1919
1920
1921
1922
1923

FIG. 5

120 acres, and the remainder is in small farm lots, from 5 acres to 20 acres in size.

The overdevelopment cannot be said to be entirely the fault of the operator, for the landowner is equally to blame. The larger operators have made earnest efforts to consolidate the small holdings into community leases, but generally tempting offers of larger royalties and bonuses, speedier drilling, and the owners' desires to have individual wells, have enticed them away from the community idea, and the promise of immediate profit has prevailed over the assurance of a larger ultimate return.

The overdrilling that has taken place in the Long Beach field represents a tremendous economic waste, not only in the expenditure of capital, but in the dissipation of natural resources. Good practice dictates that there should be not more than one well to every 5 acres. The present proved area of the Long Beach field includes about 1,200 acres. Under normal conditions, therefore, the field could be adequately developed by 240 wells. Within the proved area there are completed or drilling at the present time a total of 630 wells, or 390 wells that are entirely unnecessary. As the average cost of drilling and completing a well for production will average about $75,000, there has been spent needlessly in drilling alone, approximately $29,000,000. This does not include a corresponding needless outlay for more and larger camps, pipe lines, storage, gasoline plants, and other facilities.

Regrettable as is the needless expenditure of capital, the lavish expenditure and waste of a great resource is even more deplorable. Some of the direct results of such excessive development are a loss of oil through inadequately exhausting the oil sands, loss of gas pressure and rapid encroachment of edgewater, causing incomplete recovery and loss of gas which otherwise could have been utilized. Indirectly such methods cause an overproduction of oil and gasoline, and consequent fall in price, needless expenditure for storage, loss of oil through prolonged storage and the necessity for abnormal refining capacities.

PRODUCTION AND DECLINE OF WELLS

The decline of wells, especially in the closely drilled portions of the field, is very rapid. The curve (Fig. 6) shows the decline in

percentage of initial production. This curve is a composite based on the performance of seven groups or families of wells in different

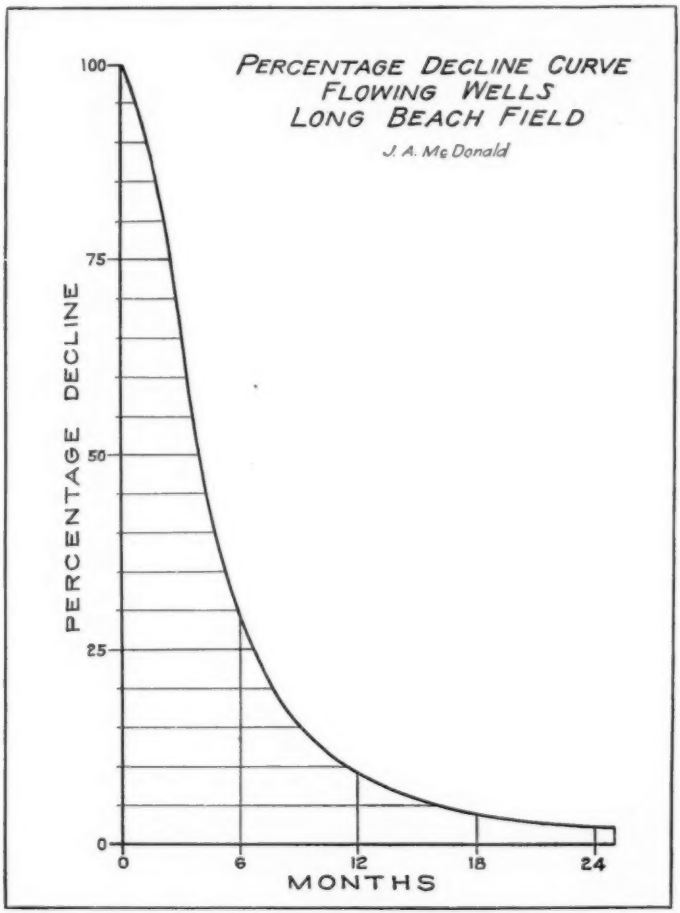


FIG. 6

parts of the field, and is believed to be fairly representative of the field as a whole. It will apply, however, only to flowing wells, as

the records of pumping wells are of too short duration to give a reliable curve. According to this curve, wells will decline to 50 per cent of their initial production in four months, to 30 per cent in six months, and to 9 per cent at the end of a year. When put on the pump, wells will maintain a much flatter curve, but with a much lower initial point corresponding approximately to the end point of the flowing curve.

No reliable estimates can be made at this time of the ultimate recovery of the field. To date the field has produced 58,000,000 barrels of oil. This is from an area of approximately 1,200 acres, which represents a recovery to date of approximately 50,000 barrels per acre.

There is no doubt that the field is very near the peak of production. Our best estimates would place the peak in December, 1923. New wells to compensate for the decline of present wells would probably maintain this peak for several months, probably until February of 1924, when we expect the production to enter a definite decline.

A REVISION OF THE TEXAS TERTIARY SECTION WITH SPECIAL REFERENCE TO THE OIL-WELL GEOLOGY OF THE COAST REGION

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The surface geology of the Tertiary belt of the coastal region of Texas has been determined and mapped with reasonable accuracy. The larger features are agreed upon by practically all of our geologists, leaving only a few details in controversy. These are due to the great similarity in the composition of certain beds of different ages and the scarcity of fossils in all beds above the Eocene.

Briefly, the various stages of the Eocene, Oligocene, Miocene, and Pliocene occupy zones of various widths approximately parallel to the present Gulf Coast. The Eocene comprises a series of marine, lagoonal, and lacustrine sediments with land deposits but sparingly represented. The post-Eocene, on the contrary, is made up almost entirely of land or fresh-water deposits with only a small amount of brackish-water sediments. No outcrops of marine deposits of post-Eocene age have been observed. Outside the coastal domes there are few marked surface evidences of faulting, folding, or other diastrophic movements, and none of these are of great extent.

However, the subsurface geology of this area, as revealed by the numerous wells, shows a very different condition. The beds exposed at the surface do not fully represent the subsurface section either in materials, manner of deposition, total thickness, or character of diastrophism. They are simply the marginal deposits of the constantly oscillating basin which, in its restricted form, is now occupied by the Gulf of Mexico, and the gulfward continuations of these marginal deposits of land and fresh-water materials in many places grade into or are replaced by brackish or marine beds. It is fully evidenced also that these marginal beds may not fully represent the time interval of each stage but only that period of the

oscillation that brought the coastal strip, in the area now exposed, low enough for their deposition. Thus, the interior lignitic deposits of the Wilcox belong to the middle stage of that formation; the basal Jackson is lacking from a large area and the same is true of the lower Oligocene, although the presence of all these beds along the coast is proved by the material in the wells.

The proof of these statements was made possible by the improved methods of examination of sediments and well samples inaugurated in the laboratory[1] of the Southern Pacific Company and now more fully developed in co-operation with the laboratories of the Texas and Humble Oil companies. The clayey material of the original well sample is largely removed by lixiviation and the remainder, after drying, is submitted to microscopic examination to ascertain its physical character, mineralogical composition, and its faunal contents of foraminifera or other microscopic forms. The probable horizon of the material is then determined by comparison with similar materials and faunas from known horizons.

The purpose of this paper is to revise a typical Tertiary section as it appears on the surface in the light of these investigations and to expand this section and to show its true relations to the subsurface geology by adding the results of similar studies of different well sections, and thus demonstrate the accuracy, usefulness, and value of this method.

Because of recent difficulties in determining the ages of sediments found in wells drilled in southwestern Texas it has been thought best to take as a type for this discussion the corresponding section along the Atascosa, Frio, and Nueces rivers, which was first described by the writer from his work in 1892 while State Geologist of Texas in a paper on the geology of southwestern Texas.[2]

The field work on which this revision is based consisted in a resurvey of the region along the rivers by Messrs. Paul L. Applin and Lyman C. Reed, and the collection of materials for comparison from type localities of Mississippi and Alabama by Miss Esther E. Richards and Miss Grace Newman, to whom we are also indebted for the laboratory investigations and determinations.

[1] *Pan American Geologist*, February and March, 1923.

[2] *Trans. A.I.M.E.*, Vol. 33 (1903), p. 913.

THE TYPE SECTION

Beginning at La Coste, on the Southern Pacific, a line was run southeastward following the main drainage of the Atascosa, Frio, and Nueces rivers to Wade, on the Aransas Pass Railway. This line corresponds very closely with the normal dip of the beds.

The Midway was not recognized in the original section. The lowest Tertiary found, brown micaceous sands with bowlders of brown quartzitic sandstone, was part of the series which includes the Lytle lignite and is of Wilcox age. Below Lytle are interbedded sands and sandy clays with some ferruginous matter and numerous beds of siliceous limestone and quartzitic sandstone. These are overlain, 3 miles below Benton, by yellow and white sandy clays which are, in turn, covered by the Carrizo sands, consisting of yellow and white micaceous sand-rock with ferruginous laminations, grit with kaolin ball enclosures, and some fossil wood. In the original section the Carrizo was included with the Wilcox giving a belt 12 miles in width occupied by this formation, which is finally covered by the brown ferruginous sands of the Marine a short distance northwest of Rossville.

From this contact to Pleasanton the exposures of the Marine consist of ferruginous sandstones and limy sands interbedded with clays and sandy clays. South of Pleasanton the brown sandstones are succeeded by clays, sands, and concretionary limestones carrying the usual Claiborne fossils. These occur from the exposure on Bonita Creek, southwest of Pleasanton, to a point about half-way between Coughran and McCoys, a total distance from the Wilcox contact of some 22 miles.

The Yegua series of interbedded gypseous and saliferous sands and clays with heavy beds of lignite, and of massive beds of sands with seams of plastic clays and kaolins, which first appear north of McCoys, extend southward to near the mouth of Borregas Creek. It is characterized by the presence of concretions, cone-in-cone structures, and beds and seams of aragonite. A few fossils were found in these beds. The width of the outcrop is about 11 miles.

The somewhat fossiliferous, lighter colored sands and clays of the Fayette, which overlie the Yegua at Peelers, Borregas Creek, and elsewhere, are characteristically exposed in the ranges of hills

which cross the river south of Campbellton, trending southwestwardly. Particularly noticeable are the amounts of volcanic dust, opalized wood, and chalcedony which appear in them. They pass below the Frio beds near Fant City, their outcrop having a width of 12 miles.

The Frio group, which succeeds these, consists of gypseous clays with sands and sand-rock. The clays weather white, although when wet they may be green, blue, red, or yellow. They contain concretions of limestone with manganese dendrites. These are the surface beds from Fant City to Nueces River, a distance of over 10 miles.

In the original section all of the deposits from the base of the Marine to the top of the Frio, as here described, were included in the Claiborne, which thus had an areal exposure of 55 miles or more. This reference of the beds was made because among the fossils found by us and determined by Professor G. D. Harris there were none which seemed to indicate the possibility of a later age for any of the beds.

Nueces River, from Kittie toward Oakville, flows along the contact of the Frio with an overlying bed of sand which in many ways closely resembles the Fayette. The sands themselves are not only similar, but the interbedded clays are also of light colors. They lack, however, the chalcedony and opaline matter of the Fayette. This body of sands and clays which we included in the Oakville and, which, so far as our examinations went, seemed entirely unfossiliferous, extends down the river for nearly 12 miles to Mikeska, just south of which, in a line of hills, these sands and clays are capped by a series of grits, sandstones, and clays carrying vertebrate fossils of Loup Fork age. Southward along Lapara Creek, beds of like composition carry vertebrate fossils of the Blanco stage of the Pliocene. The exact separation of the two series in the field was not attempted because they were so much alike that division was very difficult. Along our line of section the Oakville series has an exposure of some 16 miles and the Lapara probably 5 or 6 miles more.

The succeeding beds of clays and sands known as the Lagarto are, on the whole, of duller color and are more calcareous than the

Lapara and have manganese as one of their characteristic constituents. While these beds are exposed over a considerable area their occurrence is often masked by the overlying Raynosa which is the southwestern representative of the Lafayette formation of east Texas.

It will be seen that the original section recognized only the Lignitic phase of the Wilcox in the Lower Eocene, and the Lower Claiborne of the Middle Eocene. So far as determined, there were no representatives of the Upper Claiborne, Upper Eocene, Oligocene, or Lower Miocene. The sands of the Oakville with Loup Fork vertebrates near the top were in direct contact with the clays of the Frio which were referred to the Lower Claiborne.

Compared with the equivalents in east Texas, the Claiborne beds are more sandy and calcareous, and carry much less glauconite. The fossils are not nearly so abundant either in species or in numbers.

REVISED SURFACE SECTION

CLAIBORNE

The age of the "Marine" beds has been definitely established by an abundant fauna as Lower Claiborne. The beds of this stage rest upon the Carrizo sands, which we have also classed as Claiborne, although by some they are referred to the Wilcox. They are overlain by the Nacogdoches, Yegua, and Fayette, all of which we refer to the Claiborne.

The "Marine" was so named by Kennedy, who subdivided it into the Mount Selman and Cook Mountain. Apparently, these subdivisions are not constant, but depend entirely upon local conditions. At any rate, they are practically a unit paleontologically and a group name is desirable. As "Marine" is not well suited, after consultation with Mr. Kennedy, the name San Augustine is suggested as a substitute, since the town of that name is located near the center of an excellent section comprising both subdivisions.

As was stated earlier in this paper, the Mount Selman phase of these beds extends practically to Pleasanton, its iron-ore capping being here replaced by dark brown ferruginous sandstones.

The Cook Mountain, beginning near Pleasanton, seems to lack the predominant greensand character of beds found elsewhere and

exhibits only the calcareous phase seen at the top of the formation as at While Marl bluff on the Colorado.

Cook Mountain.—On Bonita Creek, southeast of Pleasanton, there are exposures of laminated clays and sands, overlain by black gypsiferous clays. Resting on this black clay are two bands of light brown clays, separated by a seam of concretionary limestone. The brown clays and limestone are highly fossiliferous and the fauna is characteristically Cook Mountain. South of Pleasanton, the laminated clays and sands occur with bowlders of yellow limestone carrying a similar fauna as far south as the bend of Atascosa River, east of Coughran. There we find beds of sandy clays overlain by a bed of indurated sand with greensand carrying imperfect fossils, which are of Claiborne age. We now consider this bed the top of the fossiliferous Cook Mountain and it is here overlain by a bed of brown sand at least 10 feet in thickness. The Cook Mountain age of the beds between Pleasanton and Coughran is apparently substantiated by the foraminifera found in them.

Nacogdoches.—Immediately overlying the Cook Mountain, there is a series of highly gypsiferous and sulphur-bearing gray or brown clays, weathering white and yellow and carrying large concretionary masses of aragonite with cone-in-cone structure surrounded by a thin shell of brown calcite. Selenite is not only scattered through the beds but occurs in masses and seams. Going down the Atascosa, the branches give excellent exposures of lignitic clays and sands with beds of selenite and carrying considerable sulphur. Similar beds are seen near the mouth of Dry Creek, three miles north of McCoy. These are the Nacogdoches beds.

The only fossil found in this bed was a large oyster. No foraminifera were observed in the numerous samples examined.

Yegua.—The clays which succeed the Nacogdoches are more massive, less sandy, and darker in color, but are interbedded with sands similar to those of the underlying beds. The clays are massive, jointed, and laminated, and vary in color from dark brown or chocolate through gray, greenish-gray, and green to white. In general, the dark colored clays appear in the lower part of the formation, while the light gray-green and white clays are most common in the upper portion. Beds of pure clay or kaolin are

common throughout this formation. The clays are for the most part non-calcareous; only a few at the base of the formation were found to contain lime.

The sands are massive and laminated and frequently argillaceous. Gray, brown, and blue are the common colors, with some greensands. They are medium to fine-grained and the sand beds are often lenticular.

Gypsum or selenite is the most abundant mineral after quartz, and occurs in great profusion throughout the clays and sands of this division. It occurs as crystals and in small flakes in the clays, in thin streaks or seams, and also in massive beds a foot or more thick. Gypsum is also seen in some concretions associated with pyrite, limonite, and sand. A thin bed of volcanic ash carrying leaf impressions was noted on the Atascosa. Other minerals noted are pyrite, muscovite, limonite, yellowish green glauconite, a little calcite, and some sulphur. Ferruginous streaks and concretions are common. Small fragments of carbonaceous matter and plant fiber are commonly scattered through the clays and lenses and beds of lignite or brown coal are interbedded with the clays and sands. Aragonite concretions showing cone-in-cone structure are of common occurrence, as scattered, isolated bowlders, or in beds of considerable extent. Sand concretions coated with gypsum are also present but less frequent. A thin bed of white lime concretions was seen near the base of this formation. Near the top of the Yegua, in the hills south of Peeler's Ranch, we found large dark lime septarial concretions, the cracks and joints of which are filled with quartz crystals. This has also been noted in the Jackson hills near Tilden, McMullen County. The ferruginous "cannon-ball concretions" common in the Yegua along the Rio Grande and elsewhere in Texas, while present in places, did not appear to be notably abundant along the section we have studied.

A microscopic study of the sandstones and clays shows the sand to be in fine to coarse grains, sharply angular, rough and pitted, and, for the most part, of clear or smoky quartz, but with a small percentage of gray and green grains. This character of quartz sand marks this horizon from the Nueces to the Rio Grande. The glauconite is, for the greater part, yellowish green in color and

occurs in irregular nodules with a cracked outer surface. Muscovite mica occurs and fine plates of black limonite as well as some fibrous calcite.

Both macroscopic fossils and foraminifera have been found in the Yegua along our line of section. Well-preserved forms are not abundant, but such as were found are frequent from the bottom to the top of this division. *Venericardia planicosta*, *Ostrea alabamensis*, and *Leda* sp. are most common. Fossil wood is found throughout the Yegua. Near Campbellton large tree stumps are found in place in the clay. The wood is petrified but not opalized as in the overlying Fayette and Jackson beds. A few reworked forms of Cretaceous foraminifera were found in the lower portion together with others indigenous to the formation. These include: (1) reworked, *Pulvinulina*, *Globigerina cretacea*, *Textularia globulosa;* (2) indigenous, *Anomalina ammonoides* var. and some arenaceous forms. The foraminifera so far found in the Yegua are entirely different from those in the Cook Mountain beds.

Fayette.—In our revised section, the Fayette is limited to the series of beds which is found exposed in the Lipan Hills east of Campbellton and their extensions to the northeast and southwest, where they form a north-facing escarpment which is traceable in a broken line for some 20 miles or more. This is the more northerly of the two escarpments which occur here. The beds, of which a section is given in the original report,[1] consist of a series of lignitic clays and sands with bands of sandstone, quartzite, volcanic ash, and beds of peaty material, capped by an indurated sandstone with a highly reticulated surface. These beds have a probable thickness of 150 feet.

No foraminifera were found in any of the samples collected from the Fayette in this region. The molluscan fossils included such forms as:

Venericardia planicosta
Corbula alabamensis, broad form
Corbula alabamensis var.
Meretrix trigoneata Lea
Meretrix trigoneata var.
Tellina cherokeensis Harris?
Spisula praetenuis Con.
Spisula decisa Con. var.
Meretrix sp.
Modiolus texanus Gabb
Pseudoliva vetusta var. A.
Cornulina armigera Con.
Crenella cast
Cerithium sp.

[1] "Geology of Southwest Texas," *Trans. A.I.M.E.*, 1903, p. 33.

The Fayette is included in the Claiborne stage partly on the basis of these fossils and partly because when studied microscopically the sediments seem more closely connected with those of the Yegua than with those of the Jackson. Furthermore, the separation of the Fayette from the Jackson is made necessary by the decided erosional unconformity between the beds of the two formations, such as is seen in Angelina County, where, on Shawnee Creek, the Jackson is found resting on basal beds of the Fayette while to the east the same beds of the Jackson rest upon an eroded surface of the Yegua; and again at Gates Bluff in the Colorado. A similar unconformity occurs in our section. In the hill at Peeler's Ranch, 6 miles northeast of the Lipan Hills, we find the Jackson superposed directly upon the Yegua and the Fayette entirely absent.

JACKSON

The Jackson, at its type locality, shows a series of highly fossiliferous beds some 70 feet thick. The molluscan fauna from these beds is comparable in number of species with that from the underlying Claiborne and yet, relatively, only a few forms are common to both stages. Our collections from the type localities show fully as great a difference in the foraminifera from the two formations as in the mollusca.

The east Texas Jackson has a thickness of several hundred feet and only represents the middle and upper portions. The basal beds, supposed to be represented by the Wellborn, do not extend east of the Neches.

The Jackson age of the beds is proven by the presence of typical fossils such as *Zeuglodon*, *Haminea grandis*, *Flabellum walesii*, and many others. Microscopic examination shows in addition to the molluscan fauna the presence in these beds of two distinct foraminiferal faunules, both of which, while closely related to the fauna of the type locality, and of equivalent Jackson age, are readily separable from it. Apparently, these two faunules seem to indicate different conditions of deposition rather than time of deposition. A careful study of the Wellborn beds has failed to give us any foraminifera. It would seem, however, that the typical Jackson is represented by our Caddell-Manning beds.

In the separation of the former Fayette of type section into two series, the lower or true Fayette which we still hold to be Claiborne has been called the Lipan beds, and the upper, the Whitsett beds.

Whitsett.—Above the hard sandstone which marks the top of the Lipan escarpment we find beds of greenish-gray and yellow waxy or carbonaceous clays and sandy clays, with some of chocolate color, interbedded with yellow, gray, pink, and brown sands. These sands, on the whole, are not so prominent and are finer than those of the Lipan and not so hard. Beds of volcanic ash occur. The formation is characterized by the presence of opalized wood and chalcedony. Aragonite in cone-in-cone concretions or in bedded form is common. Dark-colored septarial concretions, the joints and cracks of which are filled with quartz crystals, occur throughout the beds. These beds carry fossils in many places, and have an estimated thickness of more than 500 feet.

Numerous collections have now been made from these beds and they have been carefully studied. Of the determinable species and varieties in our collections the greater part consists of bivalves, mostly of species which are known to be of somewhat extended range. Some of the gastropods are undescribed so far as ascertained. Taken as a a whole this fauna, when compared with those described from the Eocene and with our collections from the type localities in Mississippi and Alabama, does not show a single species that is typically Jackson. With the exception of an undescribed *Cerithium* all occur in the Claiborne as well as in the Jackson and a few have not heretofore been reported from any horizon later than Claiborne. If, therefore, the determination of the age of the beds was to be made on the evidence of the molluscan forms alone, we would probably be justified in repeating the reference of these beds to the Lower Claiborne as originally made by Professor G. D. Harris, although a few of our new-found forms seem to have some affinities with the Upper Claiborne.

The resemblance of these beds to those of the Jackson of east Texas, in the quantity they carry of volcanic ash, opalized wood, and chalcedony, has been mentioned. A microscopic study shows the presence in surface samples taken from these beds of a typical Jackson foraminiferal fauna such as is found in the vicinity of

Caddell and White City. We consider that the unconformity by overlap of the Whitsett beds upon the Fayette, their lithologic similarity to the east Texas Jackson, and, above all, the identity of their foraminifera with those of the Caddell clays fully warrant our references of them to the Jackson, although the molluscan forms collected along our line of section are not distinctively of this age.

Frio.—The Frio marks a change from a formation that is characteristically sandy to one that is mostly clay. The lowest beds which can with certainty be referred to the Frio in the Atascosa section were found on the river southwest of Fant City, a short distance above the mouth of Weedy Creek. A yellow massive calcareous sand with bands of hardened light green sand is here overlain by green waxy clays with thin streaks of gypsum, rusty streaks, and cherty concretions. These clays weather white and are, for the most part, non-calcareous. Highly characteristic exposures of these beds occur up Weedy Creek for several miles. Similar beds continue down the river, some of the clays being bright green or blue-green when fresh, but all weather white and resemble caliche where exposed. Toward the middle of the section the green waxy clays and greenish sands carry bands of calcareous concretions. The upper beds are light green clays and sandy clays with calcareous concretions distributed through them, irregularly for the most part, but sometimes in lines. Some beds of brown sand occur. The final exposure of the Frio is just south of the sharp bend in the Nueces where it changes from its northeast to its southerly course. The estimated thickness of the Frio is 600 feet.

The characteristic white weathering of the clays is well shown in the hills at Fant City and in the escarpment that extends southwestward from the mouth of Commanche Creek. The clays become indurated, weather to a chalky-looking mass of dazzling white and break into small fragments along joint cracks showing a highly conchoidal fracture. The clays, however, are only slightly calcareous and seem rather silicified.

Under the microscope the differences of Frio materials from those of the underlying beds are strongly marked. Some of the washed clays show small hardened fragments of clay or shale mingled with

glossy black scales of magnetite and some brown mica, while in the sands and sandy clays we find a large proportion of materials of volcanic origin. The sand grains vary in fineness but are usually platy and angular fragments of volcanic ash. The quartz also appears in splintery, needle-like fragments and in groups of hair-like filaments scattered through the sands and sandy clays. This character of material is peculiar to the Frio beds and at times makes 50 per cent or more of the material in the beds.

No fossils except a leaf impression were found in the beds here assigned to the Frio. This is true also of the washed sediments.

The Jackson age of the Frio is indicated by the fact that we have traced what we consider to be its continuation southward to Conchos River in Mexico where it forms a good part of the mass of the Pomeranes Mountains and on the eastward-facing slopes of these mountains we find this Frio overlain by beds of fossiliferous sands and clays belonging to the Lower Oligocene.

OAKVILLE

The Oakville of west Texas is in a measure the equivalent of the Fleming of east Texas, but consists of deposits laid down in shallower water. The Fleming clays with calcareous concretions and interbedded sands are replaced here by beds predominatingly sandy, with some massive clays and interbedded and interlaminated sands and clays.

In the east our exposures indicate a period of continuous deposition embracing the upper Oligocene, all of the Miocene, and probably some of the Pliocene. Just what parts of this series are represented by the deposits of the Oakville has not yet been determined. The Oakville was evidently laid down on a gradually subsiding floor and the present surface exposures represent only an upper portion of the entire deposit. These beds are as difficult to subdivide as is the Fleming itself.

The lowest exposures show massive sands with some gravel and inclusions of balls and lenses of brown and green mottled waxy clay which carry round calcareous concretions. The interbedded clays are like the inclusions: they also carry concretions and are massive and jointed. These continue down the river to near the

mouth of Timon Creek east of George West. Below this point the sands become fewer and are in thinner beds and occur interbedded and interlaminated with the clays. They are succeeded by similar sands and clays with grits carrying vertebrate fossils of Miocene age. Above these come similar clays, sands, and grits with Pliocene vertebrates.

It was not found possible to separate the Oakville and Lapara in the field.

Washed, the sands show comparatively coarse or uneven-grained clear or light brown quartz with darker-colored quartz and chert forming 20 to 30 per cent of the whole. The clays show fragments of a finely granular speckled clay and of aragonite either as prisms or worn crystals. The sands occurring in the clays are finer, and, toward the top, more angular than those of the sand beds. Pyrite, magnetite, mica, gypsum, and a little glauconite are found as well as volcanic glass and ash. From the top downward reworked Cretaceous foraminifera were found with a few *Chara* seed.

THE WELL SECTIONS

In the materials secured from well sections of the Gulf Coast, we have to deal with deposits of very varied character. We find not only sediments which have clearly been derived from the older formations appearing at the surface of the land area to the north, but there are others, including a large quantity of volcanic materials, the source of which we have not been able to identify. The character of the sediments varies also westward, owing to the conditions of deposition. There were apparently at least three distinct basins of deposition. In the eastern portion of the state was the Sabine basin which comprised the western part of the Mississippi embayment. In the western portion was the basin of the Rio Grande embayment, the sediments of which had their origin, in large part at least, in the rocks of the mountainous region to the west and north. The difference in the sediments of similar age in these two areas is strongly marked and the intermediate area, while partaking in some measure of the character of the adjoining basins, differs considerably in details of deposits.

It is entirely possible that further study of the well sections of this intermediate area may necessitate a division of it into two portions.

COAST CLAYS

The coast clays are practically unfossiliferous so far as well sections are concerned and have had but little study. They are of very irregular thickness, having been laid down on a surface of high relief capped by the Lafayette. At Terry, in Orange County, the combined thickness of the coast clays and Pliocene was shown to be between 3,000 and 4,000 feet while at other localities in the Gulf Coast country the Miocene is found at less than 200 feet from the surface.

PLIOCENE

In the well sections, so far as present investigations show, the Pliocene seems to be represented by rather coarse, uneven-grained brown sands and brown to very dark blue clays chert and flint pebbles, and with lime nodules which are often of a terra cotta color.

In places these beds are unfossiliferous but at others, as in the Terry field, there are beds of oysters or other brackish-water forms such as *Rangia cuneata* and *Mulinea lateralis*. These beds carry *Rotalia beccarii* and *Polystomella striata-punctata* and an occasional *Quinqueloculina*—a fauna like that of Galveston beach today. Occasionally, there are beds of brown sands with many large specimens of *Trochamina inflata*, which are probably reworked from some earlier formation, most likely the Cretaceous. *Chara* fruit boxes have also been found in them.

In southwestern Texas the wells so far drilled give only the lower part of the Pliocene which consists of pink, pale green, and bluish-gray clays, gray argillaceous sands and calcareous sand rock. Washing shows well-worn even-grained sand, usually of clear quartz, with gray, greenish-brown, and red chert grains and some gray quartz. Mr. Bailey reports the presence of considerable microcline feldspar, compound grains of glauconite and siderite, and silicified rhyolite. No foraminifera were found.

MIOCENE

In the eastern portion of our region, below the materials assigned to the Pliocene formation, is found a long series of gumbos, sands, and occasional limes, approximately 2,500 to 3,000 feet thick, which vary somewhat on the different domes and in different localities, but have certain general characteristics which remain

fairly constant and seem to indicate a rather uniform set of depositional conditions. These we have assigned to the Miocene, although it is highly probable that some of the non-fossiliferous fine gray sands found at the base of the beds so classified in some of the more northern or interior domes and the fossiliferous sands, indicating beach or near-shore conditions at the base in some of the coastal domes, as at Stratton Ridge, may be the time equivalent of the Corrigan or Upper Oligocene, for no recognizable Upper Oligocene has been found so far in any of these east Texas wells.

The gumbos of the Miocene are tan, blue, blue-green, and red in color, and most often occur in the following sequence: tan gumbos near the top, followed by some reds and the blues and greens toward the base. Sometimes, as at Pierce Junction, deep purplish-red gumbo occurs near the base. Where the formation contains a large amount of gumbo, the sands, when present, occur most frequently in the lower portion. The gumbos nearly always carry many small lime nodules. The sands which wash out of the gumbos are most generally tan in color in the upper beds and gray near the base. On some domes, as at Hull and Hockley, fine gray sands and gray sandy clays make up a large portion of this series.

While beds of marine fossils of Miocene age are found in wells at a few places, including Saratoga and Batson, both the sands and the gumbos are as a rule non-fossiliferous from the standpoint of indigenous foraminifera or other fossils, but they generally carry a few small reworked specimens of the foraminifera common in the Upper Cretaceous beds, which evidently formed the source of supply for the sediments making up this formation. The upper portion of such Miocene strata is usually marked by the presence of many large secondary *Trochamina;* the middle part by smaller forms of *Textularia* and *Globigerina*, with occasional *Chara;* while the lower member has, at the top, a marine phase showing *Rotalia beccarii* (different variety from the Pliocene form) underlain by a zone which in some places is unfossiliferous, or contains only secondary forms, but at other points carries both the secondary and indigenous forms mentioned above.

The localities at which the marine phase is found in the interior are scattered and apparently only a few feet in thickness. The fossils found at Saratoga and Batson correspond with those of the

upper part of the Miocene found in the Galveston deep well. Nearer the coast there are occasional indications of a marine or brackish-water phase in this formation. In the wells studied at Stratton Ridge this was noted, once in the upper portion of the formation and again for about 1,000 feet at the base. The latter, however, may belong to Oligocene time. Still nearer the coast, wells have shown considerable thicknesses of marine Miocene as evidenced by the fossils from Houma and Bryan Heights.

The evidence at hand seems to indicate that during the Miocene similar conditions to those under which the Fleming was deposited prevailed nearly to the present coast; that during the Lower Miocene there were occasional incursions of the area by the sea and the creation, temporarily, of a marine or estuarine condition in the area as indicated by the fragments of oyster shells in the beds and the presence of indigenous foraminifera, *Rotalia beccarii*, Miocene var., *Polystomella*, sp., Miocene form, and a few *Globigerina* and *Discorbis;* and that such incursions were repeated during Upper Miocene time, taking the form of small bays and inlets which, similarly, were of comparatively limited duration. Close to the present shore only were the marine conditions more nearly constant. In this belt occasional bivalves and gastropods are found in the sediments, but the species are generally new. The foraminifera found are few in number and in species, and are those found in shallow water or along sandy beaches.

In west Texas marine conditions seem to have been entirely lacking, except along the immediate coastal belt. The well sections of west Texas show the Oakville Miocene to consist of blue and blue-gray clays and sandy clays, some pink or cream-colored clays, dark green gumbos streaked with lime nodules, and gray to green sands, and argillaceous sands at times highly calcareous or with calcareous cement and in places strongly cemented or even quartzitic. When washed the clays show uneven-grained, somewhat angular sands, fragments of light gray sand speckled with fine grains of pyrite and mica, some calcite, nodules of lime, a few aragonite prisms, *Chara* seed, and reworked foraminifera. The sands have also at times a speckled appearance, the quartz is uneven-grained, angular, sometimes pitted. It carries considerable quantities of colored quartz and chert and some volcanic ash. According to Bailey, the feldspars

are not microcline but mostly glassy plagioclase. In the tuffaceous beds, glass composes over 50 per cent of the washed material and most of the fine material is leverrierite. Obsidian is found in all samples in greater or less abundance, also grains of altered rhyolite or andesite.

OLIGOCENE

In east Texas the surface beds referred to the Oligocene are supposed to represent the Catahoula or upper member of the formation and no representative of the Vicksburg or Lower Oligocene has so far been recognized. In all the coastal wells of east Texas, however, in which the Oligocene has been certainly determined, the exact contrary is true. We find the representative of the Vicksburg, but nothing which can be correlated certainly with the Catahoula. Its only possible representative is certain beds occurring at the base of the Miocene, as already described. It is only in the well sections of southwest Texas that are found in the sequence of beds some that seem logically referable to the Upper Oligocene, and in this area the entire Oligocene seems to be more nearly of fresh or brackish-water deposition, true marine beds such as those of the eastern part of the state not yet having been found by us.

Until a microscopic study of well material had been undertaken, no marine Oligocene had been recognized in Texas. It is now known to be present in practically all of the coastal domes of east Texas and is easily recognized from its large and well-defined foraminiferal fauna. Lithologically also this Oligocene is quite distinct. The uppermost portion is usually represented by an extremely fine-grained light gray sand, followed by a dark olive green shale which is generally non-calcareous. The middle portion of the formation is often represented by a highly fossiliferous lime bed, carrying a large *Heterostegina* and the lower portion is generally sandy or a series of very fine gray sands and some gray clays. The so-called heaving shales belong to this formation. The fauna has been compared with that from the type localities of the Lower Oligocene in Mississippi, and was found to be so similar that it is considered to be the equivalent in age of the Byram Marl of the Vicksburg. Three faunal divisions of Lower Oligocene have been noted, an upper, middle, and lower, but these subdivisions vary in the general grouping of species on different domes and should be

used, we believe, only within narrow geographic limits; for example, the lower of these subdivisions at Stratton Ridge shows a return of beach conditions which we have not noted on other domes. Much work still needs to be done on these minor subdivisions. Faulting about the domes and imperfections in records help to make the problem of exact correlation and accurate stratigraphic subdivision within formations a slow process of development.

The west Texas well-sections show in beds here referred to Upper Oligocene, first, greenish-gray clays and sand rock, some highly gypsiferous clays with glauconite, pyrite, gypsum, quartz crystals, and bluish-gray calcareous sands, underlain by clays and argillaceous sands and buff, highly micaceous sandy clays. *Chara* seeds and ostracods occur in the lower portion. Some of the beds are very similar to some of those occurring in the Frio. Below this, green, tan, and pink mottled clay, chocolate, blue, and green clays or shales, somewhat calcareous, interbedded with moderately coarse sands. Washed, this material shows nodules of pyrite, some calcite, glauconite, gypsum, and a little volcanic glass.

Underlying these clays and shales we find lavender and light green clays with minute particles of pyrite, nodules of calcite and chalcedony, glauconite, and pyrite. This carries many calcite casts of *Polystomella*, *Chara* and some ostracods. Bailey reports many peculiar flat plates of marcasite, a good proportion of feldspar, mostly sanadine, and more or less distinctive concretionary masses.

EOCENE

Jackson.—The first discovery of Jackson in wells of the coastal area was that made by us in the Bissonette well at Humble where, at 3,900 feet, beds were encountered which carried a true Jackson molluscan fauna and a faunule of foraminifera which, while it contained typical Jackson forms, was much closer in character to the fauna of the Claiborne than it was to the foraminiferal fauna at Jackson or of the east Texas beds. It was therefore considered to represent a lower Jackson horizon than either of these and this seems to be borne out by other well-sections. This particular fauna has not yet been seen at the surface in Texas but Miss Kniker of the Texas Company has found it in surface specimens from northeastern Mexico. That it is really older than the faunules

of the surface Jackson has also been clearly demonstrated by Miss Kniker's work on Koehler Well No. 32 on the Humble dome, where she found the typical east Texas Jackson faunule extending from 4,000 to 5,000 feet, a thickness of fully 1,000 feet, and underlain directly by the faunule of the Bissonette well with a thickness of 100 feet or more. The same fauna occurs in the Bender-Adams well at Humble and in wells on the Hull dome.

The faunules of Jackson and the Caddell clays seem to grade rather toward the Oligocene than the Claiborne, although they are entirely distinct from these. They occur in wells around the domes at Brenham and Hockley, in the George West well in Atascosa County, the Santo Domingo well, Starr County, and elsewhere.

In west Texas the upper part of the Jackson as represented by the Frio and its extension has so far proved unfossiliferous. Its identification rests upon its lithological character.

Middle and Lower Eocene.—Very few wells of the coastal area, starting in post-Eocene sediments, have ever been drilled through the Jackson. Miss Kniker reports one well on the Brenham dome in which the drill passed directly from beds with the surface Jackson fauna into those with a Claiborne fauna, the Bissonette beds being absent.

Record of wells starting in the Eocene is very limited as to complete logs, but from incomplete logs numbers of occurrences of Claiborne foraminifera faunas are known. Thus, in a well of the Empire Oil Company in Angelina County, samples from 1,101 to 1,175 feet were Jackson, while those from 2,715 to 2,800 feet were clearly Claiborne. Below this were 200 feet of unfossiliferous sands which apparently represent the Queen City or Carrizo sands, while at 3,003 feet a fauna was encountered which contains only a single species found in the Claiborne and which seems quite surely to be Wilcox in age. This same fauna was also identified by Miss Richards from a well drilled on Idol Island, 70 miles south of Tampico.[1]

CONCLUSIONS

These generalized statements of well conditions in different parts of the coast country give an idea, at least, of the great com-

[1] *Science*, No. 1489, p. 31.

TABLE I

COMPARATIVE CHECK LIST OF THE MOST COMMON FORAMINIFERA (1) FROM THE TYPICAL JACKSON, EOCENE OF TEXAS; (2) THE JACKSON FROM THE TYPE LOCALITY, JACKSON, MISSISSIPPI; AND (3) THE BISSONETTE (LOWER JACKSON?) BEST REPRESENTED IN WELLS ON THE HUMBLE DOME, HARRIS COUNTY, TEXAS

	Texas	Mississippi	Bissonette
Haplophragmoides scitulum H. B. Brady	x		
Cyclamina cancellata Brady var	x		
Cyclamina compressa Cushman	x		x
Ammobaculites cf. *A. foliaceus* Brady	x		x
Textularia jacksonensis n. sp.	x	x	x
Textularia hockleyensis n. sp.	x	x	x
Textularia hockleyensis var. *distortio* n. var.	x		x
Textularia dibollensis n. sp.	x		
Textularia dibollensis var. *humblei* n. var	x		x
Textularia moodyi n. sp		x	
Textularia n. sp. B			x
Guadryuna rugosa d'Orbigny n. var			x
Verneullina cf. *V. spinulosa* Reuss		x	
Bolivina aenariensis Costa n. var	x	x	
Bolivina punctata d'Orbigny	x	x	
Nodosaria laevigata d'Orbigny var	x		
Nodosaria n. sp. A			x
Cristellaria vaughani Cushman var. A	x	x	
Cristellaria vaughani Cushman var. B	x		x
Cristellaria aculeata d'Orbigny	x		x
Cristellaria americana Cushman	x	x	x
Cristellaria rotulata Lamarck	x		
Cristellaria reniformis d'Orbigny var	x		
Cristellaria italica DeFrance var			x
Vaginulina linearia Montague	x		
Polymorphina cf. *P. compressa* Cushman	x		
Polymorphina communis d'Orbigny	x	x	x
Uvlgerina pygmaea d'Orbigny var	x	x	x
Uvigerina jacksoni n. sp	x		
Uvigerina n. sp			x
Globigerina dubia Eggar n. var	x		
Globigerina comglobata Brady			x
Globigerina bulloides d'Orbigny var	x	x	x
Truncatulina americana Cushman var	x	x	x
Truncatulina n. sp. A	x		
Truncatulina n. sp. B		x	
Truncatulina tenera Brady var			x
Discorbis cf. *D. globularia* d'Orbigny	x		
Siphonina reticulata Czjzek var	x	x	x
Siphonina jacksonensis n. sp.	x	x	
Anomalina ammonoides Reuss var	x		
Anomalina cf. *A. mississippiensis* Cushman	x		
Pulvinulina jacksoni. n. sp	x	x	
Pulvinulina claibornensis n. sp. var			x
Pulvinulina n. sp. B	x		
Rotalia soldani d'Orbigny var. A	x		
Rotalia soldani d'Orbigny var. B			x
Rotalia naticoidia n. sp			x
Nonionina scapha Parker and Jones	x		x

TABLE I—*Continued*

	Texas	Mississippi	Bissonette
Nonionina scapha var. *hooki* n. var	x	.....	.....
Nonionina umbilicatula Montague	x	.....	.....
Nonionina depressula Walker and Jones var	x	x	.....
Nonionina advena Cush	x	x	.....
Spiroloculina cf. *S. depressa* d'Orbigny	.....	x	.....
Spiroloculina n. sp. A	.....	x	.....
Quinqueloculina tessellata Cushman	.....	x	.....
Quinqueloculina cf. *Q. glabrata* Cushman	.....	x	.....
Quinqueloculina contorta d'Orbigny var	.....	x	.....
Quinqueloculina n. sp. A	.....	x	.....
Quinqueloculina n. sp. B	.....	x	.....
Quinqueloculina (2 sp. probably new)	.....	.....	x

plexity of beds which are encountered in wells and which, failing some such method of identification as is here outlined, present problems of correlation which are extremely difficult, if not in many cases impossible of solution. The method is by no means perfected. A few fundamental facts have been determined and the results already obtained by their application give promise that further research and investigation along the same or similar lines will yield information of greatest benefit to the well-drillers, not only of the Texas Coast, but of all similar fields.

DISCUSSION

G. D. HANNA: I should like to add a word to Mr. Dumble's statement in regard to the publications of photographs and drawings of the species of the foraminifera from different formations, both of Texas and California. One of the greatest handicaps to microscopic studies seems to be the lack of publications which picture the foraminifera of the different horizons. Until these are presented, we are going to work under a considerable handicap. The Association is urged to make every endeavor to provide some means for the publication of these which will embody illustrations of the species from the various formations.

SUBSURFACE OBSERVATIONS IN SOUTHEAST KANSAS[1]

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A knowledge of conditions of sedimentation is essential to oil-field prospecting in southeastern Kansas. While many factors are involved, it is the extent of the seas, the relief of the sea bottom, the type of material deposited, and the age of folding which are of primary importance.

THE PRE-PENNSYLVANIAN FLOOR

The geologic record of the Mississippian period in southeastern Kansas is one of widespread submergence during Waverlian time, and possibly earliest Tennesseian (Warsaw) time, when the so-called "Mississippi lime" (Boone) of this district was deposited. Then, through the remainder of Tennesseian time[2] and that part of the Pennsylvanian represented by the older sediments deposited in the Ouachita geosyncline of southern Oklahoma and Arkansas, there followed a long period of erosion. During this emergence, topographic irregularities began to develop on a gently warped limestone land area but slightly elevated above the sea. The maximum relief of this land probably never exceeded 100 feet. The warpings appear to have been expressed in the topography of this old land surface as anticlinal ridges and synclinal valleys, largely conditioned by previous folding. In a sense, drainage was away from the broadly upwarped Ozark region and convergent toward the major down-warped areas. The direction and pattern of the drainage

[1] Published with the permission of Southwestern Gas Company, Independence, Kansas.

[2] The Chester seas, by the location of their outcrop in the northeast Oklahoma, are known to have extended to within a short distance of the Kansas boundary. For short distances they may have invaded the deeper pre-Chester valleys of Labette, Montgomery, and Chautauqua counties, Kansas. Evidence at hand, however, does not substantiate this possibility.

was, however, largely controlled by local warpings. Erosion, initiated by the wearing away of the rocks on the crests of the folds, so reduced the relief that from one-fourth to one-half, and, in some cases, all of the Mississippian strata were removed from the upland ridges. As a result, the early ridges were carved into ranges of low hills with intervening transverse valleys.

CONDITIONS OF PENNSYLVANIAN SEDIMENTATION

Into this southeastern Kansas region of varying topographic expression the early Pennsylvanian seas advanced as elongated estuaries, stretching northward from the relatively shallow basins of central Oklahoma. The initial invasion probably formed the relatively narrow elongated estuary mapped by Berger.[1] In this and other restricted troughs early Pennsylvanian (Cherokee) sedimentation commenced. As successive beds of sediment were laid down, they spread laterally, overlapping the older and lower strata, and gradually accumulated higher up on the flanks of the uplands directly on the old erosion surfaces. Early Pennsylvanian sedimentation in southeastern Kansas, before complete submergence, was not one of uninterrupted sequence, but, rather, one characterized by successive transgressions and regressions of the sea, depending upon uplifts and subsidences of the land. While the old valleys were being filled with sediments, the shore lines oscillated constantly, causing contemporaneous variation in conditions of sedimentation in short distances. It was at this time that ideal conditions existed for the deposition of the so-called Bartlesville sand zone. Later, when the old valleys had been filled and several hundred feet of sediments had been deposited, the sea expanded uninterruptedly to the north and west and conditions of sedimentation became more stable and similar over the region. Near the close of Cherokee shale deposition, conditions became less stable and scattered bodies of sand were again deposited.

Henrietta time which followed may be characterized as a period of widespread uniform limestone deposition in relatively clear waters. Never again, during Pennsylvanian time, were conditions

[1] W. F. Berger, The relation of the Fort Scott formation to the Boone Chert of southeast Kansas and northeast Oklahoma. *Jour. Geol.*, Vol. 26 (1918), No. 7, pp. 618–21.

of sedimentation so stable and uniform over the entire region from what is now the Kansas–Oklahoma boundary northward. The succeeding Pleasanton submergence was very similar, although along its outcrop in extreme eastern Kansas and western Missouri conditions appear to have changed rapidly. These two divisions, forming the Marmaton group, are not readily identified in well-log sections, except in the extreme eastern counties, though by careful work the "Oswego" or Fort Scott horizon may be carried to the "granite ridge."

The overlying Kansas City group is easily identified in most localities. On the Kansas–Oklahoma boundary (T. 35 S., R. 11 E.) it has a thickness of about 400 feet, which gradually decreases to about 200 feet in T. 21 S., R. 11 E., and, finally, north of T. 20 S., R. 10 E., is less than 100 feet thick. On the Oklahoma-Kansas line this group consists of sands and shales. In T. 32 S., R. 11 E., less than 18 miles distance, fully two-thirds of the section consists of limestone. From there, northward, the section consists of thick limestones, a few thin shales, and occasionally calcareous sandstones. North of T. 20 S., R. 10 E., the comparatively thick shale, which separates the Kansas City group from the rather thick zone of Lansing limestones, is replaced by limestones. These two groups, consisting almost wholly of limestones, are separated by one thin red shale. This red shale is occasionally reported in other parts of the region. South of T. 19 S., the Kansas City limestones are succeeded by a shale as much as 200 feet thick, and a rather thick limestone. This section is distinct in places as far east as Range 11, and as far south as a line passing southeastward from T. 30 S., to T. 33 S., R. 14 E. South of these limits the Lansing limestones are replaced by shales and the group so loses its identity that it can no longer be differentiated from the underlying Kansas City group. A zone of sandstones is generally reported immediately above the Lansing limestones, and though it is best developed in Greenwood County, the horizon can be carried south to the Oklahoma line. It probably represents the contact of the Lansing and Douglas groups. The combined thickness of the Kansas City and Lansing groups, which at the Oklahoma line (T. 35 S., R. 11 E.) is 900 feet, is less than 600 feet in T. 20 S., R. 11 E.

The overlying Douglas group also thins northward. It consists of shales, a very few thin limestones, and sandstones which increase in number and thickness toward the Oklahoma line. The upper limits of this group are readily identified in well-log sections, for upward from the Oread limestone, at the top of the Douglas group, the Pennsylvanian (Shawnee and Wabaunsee) consists of a series of interbedded limestones and shales, with limestones predominating. South of T. 25 S., red beds are found at the horizon of the Oread, both above and below this limestone member.

Immediately above the Douglas is a series of interbedded limestones and shales, representing the Shawnee and Wabaunsee groups. In T. 25 S., red beds are first observed in this series. They increase greatly in number southward toward the Oklahoma line. The two groups cannot be differentiated in well logs. The base of the series, readily identifiable as far west as the Russell county oil well, is unquestionably Pennsylvanian. The upper limits, however, are difficult to determine, and a greater part of the section must be classified as Permo-Carboniferous.

STRUCTURAL FEATURES

Through the geologic epochs, Ozarkia[1] has dominated the structural features of this district. It has had an oscillating history of elevation and submergence—shown by numerous unconformities which separate the Paleozoic formations. Widespread erosion appears to have occurred in late Ordovician and early Mississippian, during the close of the Mississippian (post Warsaw) and early Pennsylvanian (pre-Cherokee–Winslow), at the close of the Pennsylvanian, and since Permian time.

Regional structure.—Southeastern Kansas lies on the westward tilted flank of the Ozark uplift, sometimes called the "Prairie Plains monocline." In a regional sense, the Permian strata lie upon a westward dipping monocline of Pennsylvanian strata in more or less non-evident disconformity. The Pennsylvanian beds in turn are superimposed upon an irregular surface of truncated

[1] Ozarkia, a large upwarped area centering in what is now southeast Missouri and extending into Arkansas and Oklahoma, was a small yet important positive element in the Paleozoic seas.

Mississippian or older strata. There are a few structural features which may be regarded as regional. The Beaumont anticline and the "granite ridge" lines of folding or settling can be carried for great distances both as surface and subsurface features. The Beaumont trend is continuous from Cambridge in T. 31 S., R. 7 E. (perhaps as far south as T. 33 S., R. 6 E.) to and beyond Eureka in T. 25 S., R. 11 E., a distance of fully 55 miles. Other regional features, as the buried Longton ridge,[1] are not evident at the surface, though it is true that there are surface "wrinkles" scattered along its axis. On the other hand, similar features are found on the surface both east and west of the buried ridge.

Local Structure.—The local structural features of southeastern Kansas seldom exceed 5 square miles in area. Deviations from the monoclinal dip of the surface beds are plunging folds referred to as "noses" or plunging anticlines, and round or elliptical domes. These structures are seldom more than 2 miles wide and more than 4 miles long. Generally, there is only slight evidence in the surface strata of buried Mississippian folds. The folds of the surface strata may be the reflection of deeper major structural features, but not all surface "noses" or folds are located over or near subsurface "structures." On the other hand, surface warpings are commonly found over, or associated with, every major structural feature of the lower Pennsylvanian or pre-Pennsylvanian beds.

In general the strata have a westerly inclination, but locally the dip and strike vary considerably. The lower strata dip at the rate of about 75 feet per mile, though the rate may be as low as 50 feet and as high as 125 feet. The dip of the surface strata is generally less than that of the underlying beds, seldom exceeding 40 feet per mile.

Folding generally shifts with depth, sometimes to the west-southwest as in the Red Bank pool at Coffeyville in Montgomery County, or to the south, as in the Rose dome area of southern Woodson County. There seems to be no hard and fast rule which

[1] The Longton ridge of Elk and Chautauqua counties has been outlined for a distance of about 25 miles. The highest part of the ridge is found in Sec. 33, T. 31 S., R. 12 E. From this point east, the base of the Pennsylvanian system drops fully 250 feet to the axis of the southeast plunging syncline in Sec. 31, T. 31 S., R. 13 E.

can be applied; better practice would be to apply the direction of shifting which subsurface studies establish for the area in question.

Origin of folding.—The structural features of this district may be due to any one or several of the following factors:

1. Differential settling of the floor, on which sediments were accumulating contemporaneous with areal subsidence, may have caused a down-warping of areas of maximum deposition, and induced a bending of the strata. Down-warping of this nature may have accentuated Berger's pre-Pennsylvanian valley of eastern Kansas and its extension northeast to Atchison and into Holt County, Missouri,[1] as well as the larger tributary valleys, as, for example, the deep pre-Pennsylvanian valley along the east flank of the Longton ridge.

2. Differential warping of the sea floor during areal subsidence may have affected only a limited section of beds in restricted localities giving rise to diastems,[2] or may have been sufficiently widespread to bring about disconformities. Where, then, warping was initiated in Cherokee times and continued intermittently along these pre-determined lines, the normal section of rocks is more or less reduced in thickness over the upwarped areas as over the Longton ridge in Elk County. There and over other large structural features of the district, in addition to a reduced section, changes in the character of sedimentation occur. These changes are more easily detected in the Kansas City and Lansing groups—shales and sands become the contemporaneous depositional equivalents of rather persistent limestone and shale members. A few folds, as, for example, the Rose dome[3] in southern Woodson County, show the normal thickness of section for that district, indicating wholly post-Pennsylvanian movement.

[1] Henry Hinds and F. C. Greene, "The Stratigraphy of the Pennsylvanian Series in Missouri," *Missouri Bur. of Geol. and Mines*, Vol. 13 (1915), 2d. ser., plate XXV.

[2] A break in sedimentation or a lost interval, represented in other parts of the district by one or more beds, has been named a "diastem" by Barrell.

[3] The Rose dome located in Secs. 18 and 19, T. 26 S., R. 16 E., and Secs. 13 and 24, T. 26 S., R. 15 E., is one of the most marked surface structures of the eastern tier of counties. It has at least 80 feet of surface "closure," covering fully ten square miles. Subsurface structure of the "Oswego" lime and the attitude of the upper surface of the pre-Pennsylvanian, which are shifted southward, are quite similar to

3. Uneven condensation or shrinkage of sediments due to differential compression of beds of limestone, shale, and sand under load is regarded by Blackwelder[1] as an important factor in the origin of Kansas surface folds and "wrinkles." There is little doubt but that some of the structural features of this district, both surface and subsurface, are the result of shrinkage or settling of sediments over buried topographic features. Pinching-out of beds by overlap against an older formation will account for much of the commonly observed thinning of strata as they approach the crests of upfolds. This is particularly true of the lower one-half of Cherokee shale deposition when sediments were filling in the drowned valleys which surrounded islands or uplands of "Mississippi lime."

Deformation of the rocks of this district appears in many cases to have been initiated in early Paleozoic time and to have continued with varying intensity along these pre-determined lines, established at least as early as the close of Mississippian deposition into post-Paleozoic time. However, folds as the Rose dome, are occasionally found, which appear to be wholly post-Pennsylvanian in time of origin.

Unconformities.—Attention is frequently called to the occurrence of oil and gas pools in erosion planes. Geologic contacts, especially between the Pennsylvanian and pre-Pennsylvanian, are of great importance in this region. The Eldorado district, which maintained a daily production in excess of 70,000 barrels daily over a period of fourteen months, obtains its oil from a reservoir—the Stapleton zone[2]—in the top of an arch of truncated pre-Pennsylvanian rocks. In the Longton district of Elk and Chautauqua counties the prolific gas-producing zone lies in the top of truncated Mississippian rocks. The gas pools are scattered along on a buried ridge (anticlinal), broken by low transverse valleys (saddles). At the apex of the

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the surface. Seven tests distributed on all slopes of the dome, except the southeast, have been drilled into the "Mississippi lime," one well, located rather low on the northwest slope, being carried to the so-called "second break." None of the wells obtained commercial quantities of oil or gas.

[1] "The Origin of Central Kansas Oil Domes," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 4 (1920), pp. 89–94.

[2] A. E. Fath, "Geology of the Eldorado Oil and Gas Field, Butler County, Kansas," Bull. 7, *State Geol. Surv. of Kansas* (1921), pp. 37–39.

hills (anticlines), the Mississippian section is less than one third as thick as on the flanks and in the adjacent synclines, signifying considerable pre-Cherokee erosion.

Knowledge of diastems and disconformities appears to be of great value in appraising Cherokee prospects in particular, as well as Kansas City and Lansing prospects.

SAND CONDITIONS

The distribution of sands or pay zones in southeastern Kansas is not well understood. In recent years, drilling sites have been located on the west or northwest flanks of surface structures. In some cases this policy has met with success, in others only with failure. Pay horizons or zones are apt to have distinguishing characteristics for each formation. They may be continuous over upwarped areas, or lie on any side of the apex of the fold. The distribution of sand bodies was largely controlled by the patterns of the sea at the time of deposition and the relief of the bottom of the seas. Sand bodies, in general, are intimately associated with overlaps. Success in picking-up sands, therefore, largely depends upon the extent of our knowledge of these conditions.

Generally, the lower sandy phase of the Cherokee, in which occurs the so-called Bartlesville sand, is best developed in pre-Cherokee valleys. Those areas which projected above the early Cherokee seas until one-half or more of the total thickness of Cherokee shales had been deposited may largely be eliminated as areas of possible Cherokee production. On the other hand, the areas of minimum Cherokee sand development are apt to have the best pre-Pennsylvanian prospects. For the higher zones or horizons no fixed relations have been observed. They are generally productive over the larger folds, especially when the folding has been intermittent throughout Pennsylvanian time.

ISOPACH MAPS

Contour maps of Cherokee shale thickness are negatives of the relief or topography of the pre-Pennsylvanian floor at the time Cherokee sedimentation was initiated, assuming that the Oswego lime was horizontal when deposited. In areas of marked pre-

Cherokee relief and in areas where folding has been intermittent throughout Pennsylvanian time, isopach maps of the Cherokee very ciosely resemble structure contour maps of the upper surface of the Mississippi lime. As the pre-Pennsylvanian ridges are generally anticlinal and the valleys synclinal, contour maps of this type are an index to the structure of the pre-Pennsylvanian. It should be remembered, however, that the upper surface of the pre-Pennsylvanian beds seldom represents the attitude of the beds. The upper surface so contoured is an irregular erosional contact plane.

OIL DEVELOPMENTS ALONG THE KENTUCKY-TENNESSEE LINE DURING 1923[1]

WILBUR A. NELSON
Nashville, Tennessee

At the Shreveport meeting of the Association of Petroleum Geologists a paper given on the oil horizons of Kentucky, Tennessee, and northeast Mississippi mentioned the new wells that had been brought in along the Kentucky-Tennessee on Kettle Creek. Since March additional drilling has been carried on in this general area, and a number of new wells have been brought in.

The recent map of Cumberland County, Kentucky, by the Geological Survey, taken in connection with the map of Clay County, Tennessee, shows that this area is covered almost continuously by one small oil pool after another, making in all one of the largest shallow oil areas in America. The area now extends in a north and south direction of over 30 miles from the old Spurrier Pool, and new Willow Grove Pool in Pickett and Clay counties, Tennessee, respectively, to the Irish Bottom and Brush Creek pools in the northern part of Cumberland County, Kentucky. While in an east and west direction, oil pools have been found for a distance of 30 or 40 miles, in Monroe, Cumberland, and Clinton counties, Kentucky, and in Clay, Pickett, Fentress, and Overton counties, Tennessee.

The oil wells, which do not average over 500 feet in depth, produce oil which has an average of 42° Baumé gravity, and some of which is around 50° Baumé; and a number of them have produced from 500 to 1,000 barrels a day flush productions. This production will rapidly diminish. This is the oldest oil pool in America, for oil was first produced here in 1820.[2] And again it is one of the newest,

[1] Read before the Association at the Los Angeles meeting, September 20, 1923. Manuscript received by the editor, March 15, 1924.

[2] M. J. Munn, *Geological Survey, Bull. 2 E*, 1911.

for it has only been in the past few years that any considerable activity has taken place and any structural geology worked out.

A structural map of parts of Pickett, Clay, Overton, and Fentress counties was published in 1919,[1] and in the summer of 1923 a structural geological map of the eastern half of Clay County was made.[2] All of the geological work in the Kentucky counties has been done by companies and is not available to the public.

There are a number of interesting facts about the geology of this region. Structurally, it lies in the region between three uplifts, the Kentucky dome and the Tennessee dome of the Cincinnati anticline, and the Cumberland Mountain uplift. It is a region of much small folding, small domes, anticlines, and synclines following each other in rapid succession. The regional dip in Kentucky is to the northeast and in Tennessee to the southeast.

The oil is found in rocks of Ordovician age belonging to the Trenton group, and in the Cannon and Hermitage formations. A study of both of these formations where they outcrop in the middle Tennessee basin or Nashville dome, just to the southeast, shows a coarse blue limestone, sandy or dolomitic in places, which is full of small crevices even now full of oil. Surface blasting or drilling has shown a number of such cavities.

In the Tennessee counties just south of the Kentucky line, the great horizon-marker of this region, the Chattanooga black shale, the basal formation of Mississippian age, rests on the Leiper's formation of the Trenton group of Ordovician age; but as one goes north of the Kentucky-Tennessee line very sandy and shaly regular thin-bedded greenish blue limestones, which are probably the Saluda formation of Silurian age, start to come in. At the mouth of Kettle Creek in Clay County, Tennessee, none of these beds occur, while near the head of this creek in Cumberland County, Kentucky, at least 15 feet of this formation occur, and still farther north at Burksville, the county seat of Cumberland County, Kentucky, there are 60 feet of this formation.

[1] Charles Butts, "Structural Geology of the Northern Third of Standingstone Quadrangle," *Tennessee Geological Survey, Bull. 24 A*, 1919.

[2] E. S. Perry, "Structural Geology of the Lillydale Sheet," Manuscript of Tennessee Geological Survey.

The interfingering of this formation into the rock strata of this section makes the accurate working out of the structure of the oil horizons, when using the Chattanooga black shale as a datum plane, a very interesting and somewhat complicated affair. It is certain that some of the dry holes drilled in Cumberland County, Kentucky, in the past few years can be traced to the fact that this interfingering of the Saluda between the Chattanooga black shale and underlying Trenton was unknown. The ancient sea in which the Saluda formation was deposited was a northern extension of the Gulf of Mexico, extending up into what is now middle Indiana and Ohio, taking in the northeastern part of Alabama, and practically all of Tennessee and Kentucky, but containing two large islands, occupying the area which is now central Tennessee and the central basin of Kentucky. The area in Clay County, Tennessee, where this formation does not occur, was part of this ancient central Tennessee island of Saluda time.

A recent study of the Kettle Creek and Willow Grove pools shows that the oil comes from horizons 240 feet, 260 feet and 535 feet below the Chattanooga black shale, and that the base of the Trenton formation occurs 535 feet below the base of the Chattanooga or 20 feet above the bed of bentonite found in these wells and known as "Green Pencil Cave."

To the south, in Tennessee, the horizons of these oil sands come to the surface in the vicinity of Carthage Junction. The oil occurring 535 feet below the Chattanooga black shale comes from the base of the Hermitage formation. This is the original Sunnybrook sand which has produced oil in a few restricted areas. The Hermitage formation was laid down in a sea which extended northward from the Gulf of Mexico and covered most of middle Tennessee and practically all of Kentucky, as well as several of the northern states. It appears that the lower Sunnybrook sand occurs in the base of the Hermitage. This being the case, this oil horizon could only be found in middle Tennessee along the Kentucky line and in the southern part of central Kentucky.

The two upper oil horizons at 240 and 260 feet below the Chattanooga black shale occur in a formation known as the "Cannon limestone" of the Trenton group. The exact relationship of this

formation (which is named from Cannon County, Tennessee) to the Trenton group was worked out during the summer of 1922 by Dr. R. S. Bassler and E. O. Ulrich. The Cannon formation is composed of layers of dove and gray limestone, both porous and tight.

Just southwest of the Kettle Creek Pool, in Cannon County, Tennessee, this formation, which is there well exposed, has a thickness of 250 feet, while at Nashville, Tennessee, 75 miles to the west, it is either absent or only 5 to 25 feet thick. The entire extent of the Cannon sea has not yet been determined, but we know that its western shore line was in the vicinity of Nashville in north middle Tennessee, and around Fayetteville, Tennessee, just north of the Alabama line. The fact that this formation is absent or very thin on the western side of the Nashville dome would account for the fact that in this section no oil in paying quantities has been found several hundred feet below the black shale, even where favorable structure exists.

COST OF DRILLING IN KETTLE CREEK AREA

The contracts for drilling in the Kettle Creek area range from $2.50 to $3.00 a foot, and if the cost of moving the machine is exceptionally heavy, the operator pays that, amounting to from $250.00 to $1,000.00 according to distance and obstacles to be overcome, the larger amounts being rare. The wells being shallow, mostly around 300 feet and never over 1,000, the cost of casing is small, the shallow wells being cased down to the sand usually and the deeper ones through the Pencil Cave, about 600 feet down.

PRODUCTION AND DISTRIBUTION

The flush production of the wells is interesting. It runs from 10 to perhaps 1,500 barrels. The lack of pipe-line facilities has not permitted the proper measurement of flush productions and all that is known is the estimate of each well based on the time it takes to fill the lease tankage. Many of the wells are very impressive when they come in and run wild for a time.

There are such inadequate pipe-line facilities that none of the wells in the field have been reduced from flush production, and many

of the wells that have been drilled in for months still flow when opened up. There are no records for the old wells.

An analysis of the oil from the Marcum No. 1 well at Willow Grove, Tennessee, is as follows: Crude oil—color, reddish-brown; fluorescence, dark green; specific gravity at 15.5° C. equals .8235, equals 40° Baumé; sulphur equals 0.13 per cent; Engler distillation test, initial boiling-point, equals 47° C.

	Percentage by Volume	Percentage by Weight	Specific Gravity	Baumé Gravity
Naphtha—to 150° C.	26.0	22.7	.7185	64.9°
Burning oils—150 to 300° C.	35.0	34.3	.8061	43.7°
Lubricating oils and residue over 300° C.....	39.0	43.0	.9080	24.2°

OIL SHALE IN SANTA BARBARA COUNTY, CALIFORNIA[1]

F. D. GORE
Santa Maria, California

INTRODUCTION

California produces oil from natural resources in three ways: (1) drilling to underground reservoirs from which oil flows or is pumped; (2) extraction, by means of solvents from bituminous rock; and (3) destructive distillation of oil shale. The first method is, of course, the most important. The second is practically of no interest now, for while California has numerous easily accessible deposits of bituminous rock, the process of extraction is comparatively costly. The third process is becoming more important as the oil obtained from bituminous shale is peculiarly adapted to use as flotation oil, an oil used in the recovery of sulphide minerals in ores.

A COMPARISON OF CALIFORNIA OIL SHALE WITH OTHER SHALES

The oil shale of California should not be confused with the shales of other parts of the United States and foreign countries, as it is different both physically and chemically. It is in a truer sense an oil-saturated diatomaceous shale from which oil may be extracted by the use of any of the well-known solvents such as benzol, chloroform, pyridine, etc.

Utah and Colorado shales are similar to the Scotch shales in the character of their kerogen content. New Brunswick shale, on the other hand, differs slightly in that it resembles a torbanite. The shales of Indiana, Illinois, and Kentucky vary considerably, some of the deposits resembling the Utah and Colorado deposit,

[1] To Mr. G. W. Wallace, consulting engineer, and Mr. F. G. Green, chemist for the N. T. U. Company, the writer wishes to acknowledge thanks for information concerning the different chemical analyses of shale oil. To Dr. David T. Day the writer is indebted for information concerning the Day Process of oil extraction.

with the exception that the oils produced as a result of destructive distillation contain a higher percentage of so-called tar acids (phenols and creosotes); in fact, shales are known in Illinois which yield oil similar in every respect to the low-temperature distillation

TABLE I

PHYSICAL PROPERTIES OF DIFFERENT OIL SHALES

Source	Moisture	Volatile Material	Fixed Carbon	Ash	Sulphur	Approximate Percentage of Extraction by Solvents	Nitrogen
Nevada	2.4	29.3	4.2	64.4	4.	.....	.43
California	6.67	25.41	5.37	62.55	1.8	9–22	.....
Utah	.75	41.95	2.80	54.50	2.1	1.0	.60
Colorado	1.3	21.7	16.3	60.7	1.1	2.4	.70
Wyoming	.2	35.3		64.5	.....	1.75	.40
Kentucky	.7	28.6	0.7	70.0	3.8	.14	.60
New Brunswick	1.5	16.0	4.5	78.0	1.2	0.8–2.5	.....
Scotland	1.0	22.0	4.0	73.0	1.4	1.9–2.4	.5–.9
New South Wales Capertee	1.05	46.52	32.13	20.2	.35	.3	.3

products from coal, containing, in some instances, as high as 30 per cent tar acids. This indicates that some of these so-called shales are in reality a low-grade cannel coal. The shales of Utah, Colorado, and New Brunswick contain a solid bitumin which, when

TABLE II

DISTILLATION TEST ON SAMPLE OF CALIFORNIA OIL SHALE NEAR CASMALIA*

Initial boiling-point	212° F.
Water	0.5 per cent
Oil distilled at 425° F. 0.8 per cent—Spec. gr.	.8396—36.7° Baumé

* By Smith, Emery & Co.

destructively distilled, yield an oil. This bituminous matter is insoluble in any of the well-known solvents, and the oil is only obtained as a result of destructive distillation reactions. The spent shale or residue from both the Colorado and Utah shales are largely silicates of one form or another, having a high aluminum content, whereas the California shale residue is high in silica.

Distillation continued with steam, collecting the distillate in 10 per cent fractions as follows:

TABLE III

	Fractions (%)	Temperature (F.)	Specific Gravity at 60° F.	Baumé
1	10	535°	.882	28.7°
2	10	600	.917	22.7
3	10	655	.941	18.8
4	10	676	.965	15.1
5	10	738	.983	12.4
6	10	760	.995	10.7
7	15	765	1.005	(Heavier than water)

The residue in the still-bottom consisted of a soft, asphaltic material, composing about 34 per cent of the original oil.

As the first two fractions of the steam distillate were very low in viscosity at ordinary temperatures, while the fractions 3 to 7 were somewhat viscous, the distillate was divided into these two portions and tested as follows:

TABLE IV

	Fractions 1 and 2	Fractions 3 to 7 Inclusive
Specific gravity at 60° F.	.906	.979
Baumé	25.0°	13.0°
Flash	180° F.	285° F.
Cold test	Below −40° F.	+25° F.
Sulphur (S)	3.69%	4.47%
Nitrogen (N)	0.18%	0.31%
Unsaturated compounds	34.71%	50.39%
Viscosity, Saybolt at 100° F.		124 seconds

LOCATION OF DEPOSITS

The principal deposits of oil shale occur in Santa Barbara and Ventura counties, in and near the present producing oil fields. The production of oil in the Santa Maria, Casmalia, and Lompoc oil fields is obtained from this oil shale, commonly termed "brown shale."

The areal map (Fig. 1) shows the location of the principal deposits. The data necessary for plotting the different deposits

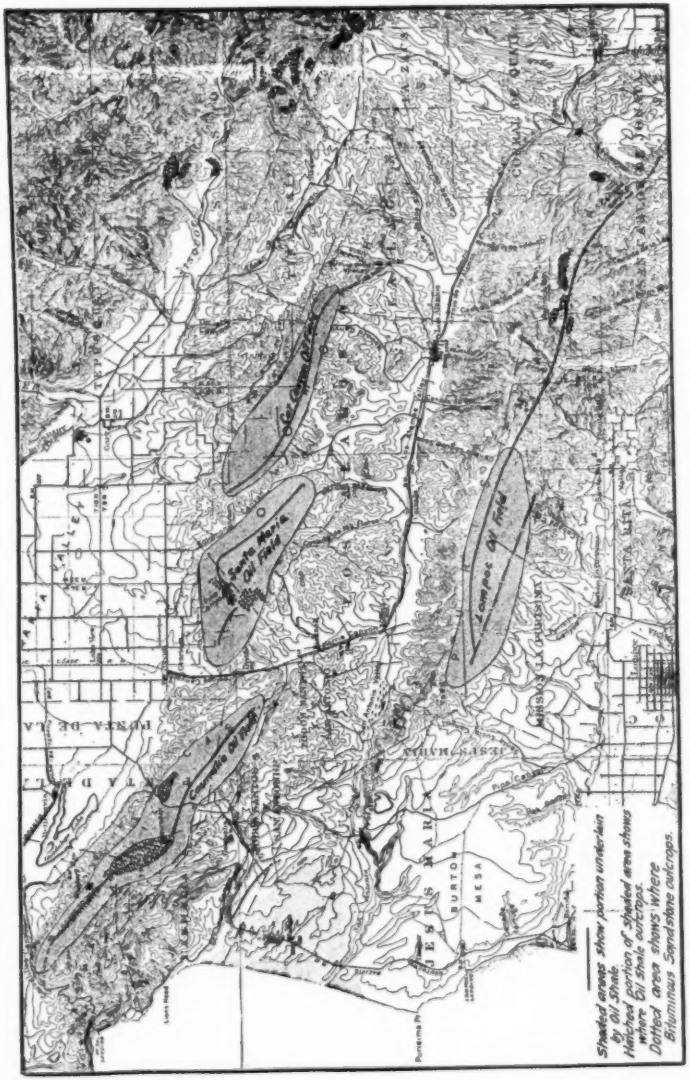
Santa Maria Oil Field
Lompoc Oil Field
Casmalia Oil Field
Shaded areas show portion underlain by Oil Strata.
Hatched portion of shaded area shows where Oil Strata outcrops.
Dotted area shows where Bituminous Sandstone outcrops.

FIG. 1

was obtained by a careful survey of the different structures in and near the oil fields of Santa Barbara County, and by a study of the logs of wells drilled in this area.

TABLE V

REPORT OF ANALYSIS OF NEW BRUNSWICK SHALE AND BY-PRODUCTS—SEPTEMBER 24, 1921*

Distillation Test of Oil Recovered

Initial B. P. 216° F. (10 Per Cent Fractions) Sp. Gr. Crude Shale Oil .908

Acid Loss	Fractions	Temperature	Sp. Gr.	Flash P.	Burn	Cold Test	Paraffin	Aromatics	Unsaturated Hydrocarb.	Nitrogeneous Oils	Phenols	Saturates
28.4	10%	401	.787	32	46	.....	49.9	21.7	26.1	2.1	.2	71.6
28.2	20%	484	.826	108	117	.....	53.9	17.9	24.4	3.8	.6	71.8
35.8	30%	540	.854	160	176	.....	43.0	21.2	30.9	3.8	1.1	64.2
35.4	40%	604	.875	210	234	.....	37.5	27.1	29.9	4.3	1.2	64.6
40.0	50%	609	.884	148	218	.....	29.7	30.3	34.0	4.9	1.1	60.0
46.0	60%	625	.880	72	120	58	29.9	24.1	40.9	4.9	.8	54.0
50.6	70%	620	.888	60	116	44	32.8	17.6	46.6	3.8	.3	50.4
49.4	80%	634	.900	56	88	48	37.9	12.7	46.0	3.2	.2	50.6
49.7	90%	590	.926	62	114	50	42.0	8.3	46.7	2.7	.3	50.3

	Analysis of Shale	Analysis of Residue	Gas Analysis	
Moisture	1.55	.....	CO	24.6
Volatile matter	15.21	2.85	III†	14.3
Fixed carbon	4.06	7.88	O_2	.....
Ash	79.08	89.27	CO	12.1
Sulphur	1.36	1.18	CH_4	21.8
Nitrogen	.....	.....	H_2	16.8
			N_2	10.4
			B.t.u., 593.5 per cu. ft.	

Ammonium sulphate recovery—30 pounds per ton.
Sulphur in the oil—1.2 per cent.

* By F. G. Green, chemist.
† Illuminants or such hydrocarbons as are heavier than methane.

The major portion of deposits which would justify exploitation are easily accessible by wagon roads and are an average distance of 2 miles air line from the railroad station of Schumann.

GEOLOGICAL CONDITIONS

The larger beds of bituminous shale appear in the lower calcareous and flinty series of the Monterey shales of the middle Miocene period. Due to the highly fractured state of the beds caused by folding, a reservoir for the accumulation of oil is formed.

These bodies of bituminous shale are overlain with the upper series of the Monterey shales and in places by the Fernando formation and Terrace deposits.

TABLE VI

REPORT OF ANALYSIS OF COLORADO SHALE AND BY-PRODUCTS, AUGUST, 1921

Distillation Test of Oil Recovered

Initial B. P. 185° F. (10 Per Cent Fractions) Sp. Gr. Crude Shale Oil .912

Fractions	Temperature	Sp. Gr.	Flash P.	Burn	Cold Test	Acid Loss
10 per cent...	388	782	.....	.....	.....	9.4
20 per cent...	459	829	99	120	.....	10.8
30 per cent...	523	864	159	170	.....	16.0
40 per cent...	590	892	208	237	.....	30.0
50 per cent...	629	906	232	264	44	28.0
60 per cent...	640	911	96	212	53	34.0
70 per cent...	590	875	58	98	52	22.0
80 per cent...	617	886	64	80	53	22.8
90 per cent...	685	903	63	86	55	36.2
92.2 per cent..	.....	950	52	64	87	13.5
End point....	716	Loss, by volume 7.8%; by weight 1.32%				

Ammonium sulphate recovery—19.8 pounds per ton.

	Analysis of Shale	Analysis of Residue	Gas Analysis	
Moisture.....	1.29	0.79	CO_2.....	7.5
Volatile matter.....	21.72	0.95	III*.....	3.1
Fixed carbon.....	16.31	7.10	O_2.....	0.0
Ash.....	60.68	91.16	CO.....	5.0
			CH_4.....	32.0
			H_2.....	41.9
			N_2.....	10.5
			B.t.u. per cu. ft., 561	

* Illuminants or such hydrocarbons as are heavier than methane.

Wells in the Santa Maria field have penetrated oil shales at an average depth of 2,000 feet and in the Casmalia field at a depth of approximately 700 feet, gradually becoming shallower in a northwesterly direction along the Schumann anticline until the base of the Monterey shale is exposed and the underlying Vaqueros formation outcrops.

The relation of the bituminous shale to the overlying formations depends entirely upon the porosity of the upper shale beds due to fracturing. There are portions of the anticline where sharp folding

has caused fractured zones to extend from the main body of bituminous shale to the surface, and it is here that the oil from below has migrated upward, impregnating the upper bodies of shales. At these locations not only are the shales saturated with oil, but all the seams and fissures are filled with asphalt, due to the evaporation of the higher volatile substances in the crude oil. Such conditions exist at different points on the Schumann anticline, starting at the railroad cut at Schumann Station and following the anticline in a northwesterly direction to Corralitos Canyon.

The amount of overburden varies considerably on all of the deposits. Data concerning it were obtained by digging pits until the brown shale was encountered. The overburden will offer no serious handicap during the mining of the shale, as all of the work may be open cut and can easily be stripped by steam shovels. The overburden consists of unproductive Monterey shale, overlain by a small deposit of silt and decomposed vegetable matter. This area is sparsely covered with scrub oak bushes and brush.

EARLY OPERATIONS

Since 1900 several attempts have been made to mine the asphalt deposits of this area, and it is reported that the operations were profitable, as a high-grade asphalt was obtained. In later years, however, the oil industry and the manufacture of asphalt brought the price so low that the asphalt mines mentioned had to be abandoned.

One company, operating what is known as the Waldorf mine, drove a tunnel into the hill to a distance of 1,500 feet, following a fissure, which was filled with asphaltum. This mine has long since been abandoned and is now unsafe for entrance.

OPERATING COMPANIES

The Day Company.—Dr. David T. Day is operating an experimental plant at the railroad cut near the station of Schumann. The Day Process is one of destructive distillation and cracking to obtain lighter oil for the purpose of making gasoline and lubricating oils. The method of mining is by open cut. Small dump cars are filled with shale and conveyed to the crusher on a small track.

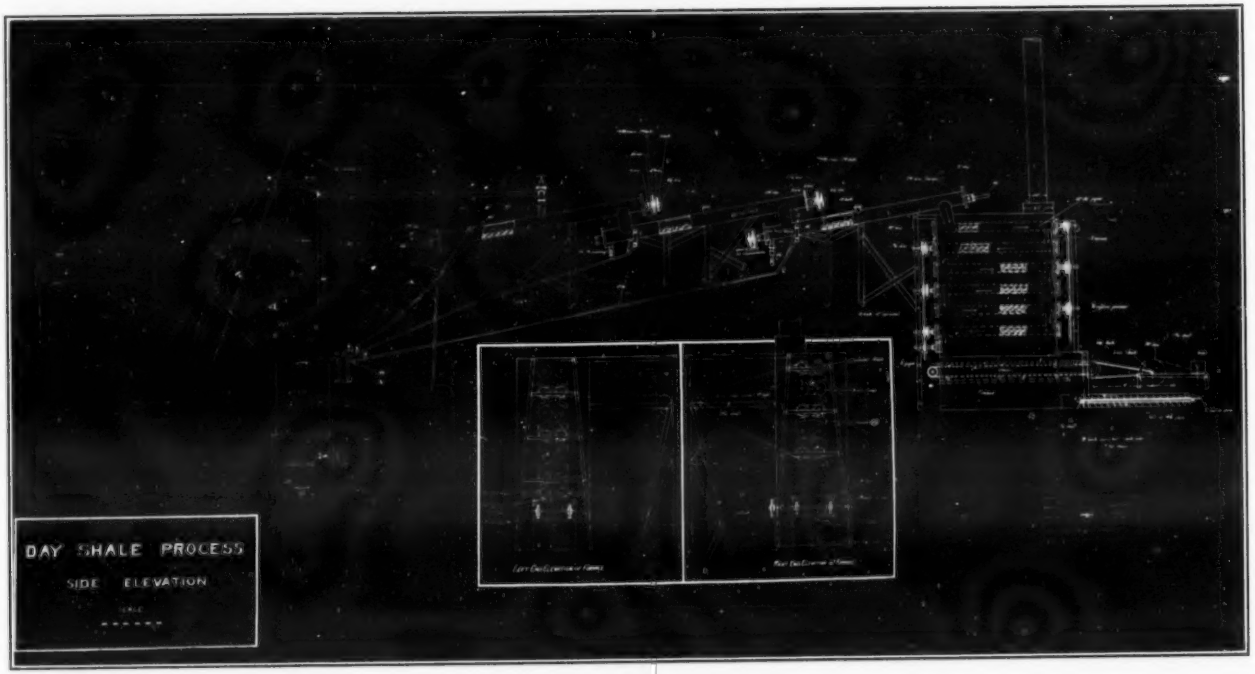

FIG. 2

The shale is dumped into crusher bins and from there into crushers where it is reduced to the size of about 1½ inches in diameter. From here it is conveyed to another bin which has an adjustable outlet which determines the rate of feed to the tubular screw conveyors, as shown on the flow sheet, Figure 2. The shale travels through the three tubular screw conveyors to the retort at a predetermined rate of speed for maximum extraction of oil. As the shale enters the retort, where an average temperature of about 800 degrees F. is constantly maintained, destructive distillation is begun. The higher volatile materials are driven off first, and distillation is continued on down to the residuum as the shale approaches the fire box. Enough carbon remains in the shale to maintain a constant heat in the fire box or combustion chamber, which slowly deposits the spent shale by means of a LaClede-Cristy chain stoker to an endless-chain drag which deposits the spent shale at the dump.

As the gases are driven from the shale upon entering the retort they follow back through the tubular screw conveyors and are partially condensed upon encountering the cold shale. As condensation takes place the incoming shale is preheated to a certain extent, and given a bath of oil, and as the oil is fed back toward the retort, cracking takes place, which results in a high-gravity product. The average amount of oil obtained is about 30 gallons per ton of shale. According to data furnished by Dr. Day, the resultant product contains:

	Per Cent
Gasoline	30
Kerosene	15
Gas-oil	15
Lubricants	30
Residuum and loss	10

The crude oil contains from 1 per cent to 3 per cent pyridine bases.

The N. T. U. Company.—The N. T. U. Company has been operating for the past year on what is known as the Stokes property near Casmalia. On this property are located some of the largest deposits of oil shale in the area under consideration (Fig. 3).

FIG. 3

A 20-ton plant (Fig. 4) was erected for experimental purposes and the results obtained were so satisfactory that the company is now erecting a large commercial plant comprising 25 units of 40-ton capacity each, which will handle 1,000 tons of shale per day. The open-cut method of mining will be followed and the shale delivered to the battery of generators by means of a standard gauge railway dump car of 40-tons capacity. In this process it is necessary to crush the shale to pieces of 2-inch diameter. The car containing the shale from the quarry, which has been crushed to the desired size, is dumped directly into the generator. The principles involved in the practice of this process differ from retorting methods in that direct internal combustion on the non-oil-forming combustible matter contained in the shale is utilized. The combustion is caused to travel progressively downward through a mass of shale contained in a closed chamber, thereby furnishing heat which, traveling downward in advance of combustion, creates a working zone in which the oil is distilled from the shale, either by destructive or simple distillation. None of the oil comes in contact with the hot zone of combustion, as all of it travels progressively downward in advance of the combustion to the bottom of the chamber where it is recovered; whereas, in the recovery of oil from shale in all retorting plants, the method used involves the external heating of a retort or chamber containing the charge of shale.

The process used by this company is fully patented and the patents are owned by the S. E. Company, the N. T. U. Company holding the United States license.

The parts used in process consist, of a generator, condenser, and scrubber. Referring to the flow sheet (Fig. 5), the generator is first filled with oil shale and fired at the top. The top is then closed, allowing only sufficient oxygen to enter for the purpose of complete combustion. A vacuum is placed on the outlet pipes by means of an electric fan and the direction of fire brought downward through the cold shale. Sufficient vacuum is applied to regulate the proper burning of the shale for the purpose of obtaining the maximum amount of oil and gas therefrom. As the gases are driven off by heat they are partially condensed by encountering the cold shale, and are further condensed in passing through the condenser and scrubber.

FIG. 4

This process of extraction does not crack the oil excessively, and as a result the crude oil contains certain properties that make it very desirable for use as flotation oil in the recovery of sulphide minerals in ores. By this process it is reported that over 90 per

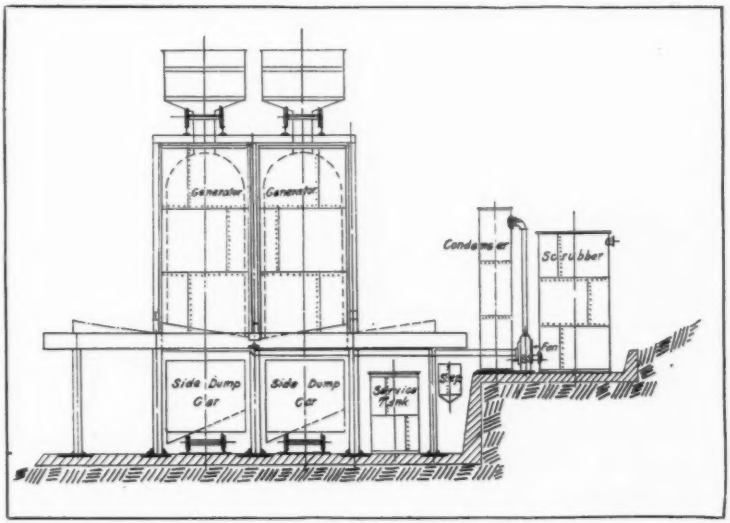

FIG. 5

cent of the total shale oil can be recovered. The gravity of the oil is about 14 degrees Baumé. As much as 40 gallons to the ton have been obtained. However, the average runs between 30 and 35 gallons to the ton.

SHALE OIL VERSUS COMMERCIAL CRUDE

It is not likely that shale oil will for many years hence replace our present crude oil as obtained from wells. This is due largely to the chemical properties of the shale oil. When first obtained the oil has a gravity of about 14 degrees Baumé, and is very low in viscosity. It is bright green in color. When exposed to sunlight the bright green hue is lost and it becomes a dark brown with an increase in viscosity. These changes are apparently

due to oxidation hastened by the catalytic effect of the high sulphur content of the oil. The removal of the sulphur compounds is the chief difficulty to be met with in refining. Aromatic hydrocarbons constitute the largest percentage of the oil. Tar acids and nitrogeneous oils are present in very small quantities. Shale oil readily emulsifies with the water present in the shale during the process of extraction, and is more difficult to dehydrate than the ordinary crude petroleum.

FUTURE POSSIBILITIES OF THE OIL-SHALE INDUSTRY IN CALIFORNIA

According to estimates made from available data, there is an existing market of approximately 5,000,000 gallons per year of flotation oil. Should shale oil as produced in Santa Barbara County substitute for higher-priced collective agents now in use by the mining industry, the extraction of oil from shale will be one of the important industries of the state.

The oil-shale industry in its present stage of development is not comparable to the petroleum industry. The methods of obtaining and refining the oil are entirely different, and the problems connected with the refining of shale oil are more complex than are those of refining petroleum.

To be successful, a company formed for the purpose of producing shale oil must be sound financially and able to procure high technical and business ability. It should also be prepared to carry on exhaustive experiments, and be satisfied with a very slow return on the money invested.

OIL GEOLOGY AND SCIENCE[1]

K. C. HEALD
United States Geological Survey, Washington, D.C.

The ability of the average oil man to bound from one extreme to another makes a lively rubber ball look like a lead slug. Hardly had the peak of the worst overproduction in years been passed than he began to wag his head and talk of a rapidly approaching shortage of oil; and this while we were still putting oil into storage faster than we could take it out. The worst of it is, he is probably right, although overproduction is still with us. The chances are so much in favor of his being right that it would be folly not to take stock and see how such a shortage may be met. Is a shortage going to come in spite of oil geology? It has been noticeable that geologists have not gotten hoarse refuting the accusation that they, through development of skill in hunting for fields, are responsible for the overproduction of the past year. Yet one listens in vain for statements that this skill will lead to the discovery of new bonanza fields in time to prevent a shortage. Does it mean that geologists fired all their heavy artillery ammunition in one tremendous broadside and have nothing but small arms left? Or that all the bonanza fields have been discovered? Or does it mean that the simultaneous development of eight marvellous fields was one of the most astounding coincidences in the history of the search for any mineral, and that oil geology has a long hill to climb before it will reach a stage of development where a similar feat can be performed?

Never since geology was first applied to the search for oil has the need for more knowledge been more cryingly apparent. We can proclaim that "we did it" when the wonder fields of 1922 and 1923 are mentioned, but it is safe to predict that not a reputable geologist in the country will stake his reputation that we can do it again. There are too many things we do not know. Some of those things

[1] Manuscript received by the Editor, February 13, 1924.

can be revealed only by exploratory drilling, but many of them are simply due to ignorance. The oil geologist is short on fundamentals. He knows that many things are so, but he does not know why, and without the "why" he must speculate instead of dealing with certainty. For example, it was long ago learned that oil pools often are present in anticlinal folds. Then it was learned that folds in rocks deep below the surface often conformed only vaguely to those manifested by the surface beds, and that, as the oil adjusted itself to these deep-lying anticlines, the structure of the surface beds had to be interpreted in terms of its significance in the deeper rocks. Some anticlines carry oil on one flank, some on both, some in irregularly distributed patches. The reasons for irregular distribution have been given in few instances, and anticipation of the irregular conditions is practically unheard of. Anticipation will not be possible until we know *how* and *why* rocks vary in porosity and texture, *why* oil migrates and *how* it does it, *how far* it will move, what kind of beds it *originates* in, the *time* necessary for oil to form, which, in turn, will tell whether it probably migrated during the first period of folding, and, finally, the *type of matter* that oil *originates* from. Until we can answer this last we cannot answer the preceding queries. We can speculate on them, but we cannot know. In short, in almost any thorough study looking toward improving the technique of oil finding, the geologist is confronted by a door he cannot open, and the key to that door is knowledge of the genesis and alteration and migration of oil and gas.

There is no reason why oil geology should not make enormous advances, and those soon. The problems that confront us are no more difficult than those that have been successfully solved by economic geologists who have specialized in metallic minerals. To be sure the field of oil geology is much broader than the field of metalliferous economic geology; but consider the relative numbers of geologists at work on the two subjects. There probably are now in the United States as many petroleum geologists as are engaged in all other lines of geologic endeavor. Nor do the oil geologists have to apologize for past achievement. They can with justice state that they have taken up stratigraphy and the deforma-

tion of sediments where other geologists left off, and have gone forward, and that they are responsible for important discoveries and applications of paleontology and petrography, but, after all, these are contributions to stratigraphy, structural geology, paleontology, and petrology. Such contributions are essential, but they will not take the place of knowledge about oil itself and the things oil does.

What can we do about it? Work. Study. Experiment. And most of all get together and improve ideas and theories by discussion, argument, and the accumulated experience of others. Keep in touch with men and organizations that have facilities for doing what individuals cannot. The number of such men and organizations probably is realized by few. Preliminary work by the Committee on Studies in Petroleum Geology of the National Research Council has permitted preparing the list given below, but this is only a start. Not a third of the colleges and universities of the United States are represented on it. Certainly, there is no lack of workers —scientists who will gladly co-operate with the oil geologists. Nor is there lack of incentive; for the rewards, both scientific and financial, for successful work are obvious. If oil geology does not record scientific and economic discoveries during the coming five years that will surpass those of the past five years, oil geology and geologists will have failed to grasp an unparalleled opportunity and to meet what is truly their obligation to the nation and to science.

In the spring of 1923, a questionnaire was prepared by the Committee on Studies in Petroleum Geology of the National Research Council and was sent to 119 universities, colleges, and foundations, or other bodies in the United States and Canada interested in research. This questionnaire was an attempt to list research topics that promise to be important in the development of petroleum geology. It was hoped that not only would information regarding work in progress be received, but that suggestions conveyed by this list of desirable studies might incite new work by men not now actively working on oil geology.

Fifty-five replies brought the information that eighty-four men were at work on or were interested in one or more studies that had a direct or indirect bearing on petroleum geology. Very few of these

men, whose names are listed below, are actually engaged in petroleum geology, which makes the knowledge that they are engaged on the projects mentioned of double importance.

PROFESSOR GEORGE I. ADAMS, University of Alabama, University, Alabama, is working on possible relations between greensand and the origin and occurrence of petroleum.

W. E. ALLEN, Scripps Institution for Biological Research, La Jolla, California, is working on the biology and chemistry of plankton, and especially phytoplankton. This study may prove to have a direct bearing on the origin of petroleum.

PROFESSOR HAROLD L. ALLING, University of Rochester, Rochester, New York, has specialized on the microscopic study of sedimentary rocks.

PROFESSOR RUFUS M. BAGG, Lawrence College, Appleton, Wisconsin, is prepared to undertake both investigations in micropaleontology and correlation of sandstone materials from oil and gas-well logs. Studies of carbonaceous shales are also contemplated.

PROFESSOR F. E. BARTELL has studied laws controlling migration of fluids through porous bodies. U of M

R. S. BASSLER, United States National Museum, Washington, D.C., has specialized on micropaleontology, working particularly with bryozoa and ostracoda. Tertiary and Quaternary bryozoa of North America have been monographed. Data for monograph on American Mesozoic and Cenozoic species of bryozoa are being accumulated.

PROFESSOR ARTHUR R. BAUDER, department of physics and electrical engineering, University of Alabama, University, Alabama, is developing electrical method for determining presence of oil by resistance measurements.

PROFESSOR EUGENE C. BINGHAM, department of chemistry, Lafayette College, Easton, Pennsylvania, has been working on viscosity of petroleum.

PROFESSOR R. M. BIRD, University of Virginia, Charlottesville, Virginia, has in hand the problem of association of vanadium with asphalt. Results of past work have been published and plans made for future work.

PROFESSOR C. A. BONINE, department of geology, Pennsylvania State College, State College, Pennsylvania, is studying the origin of the oil shales of the Steele and Niobrara formations of Wyoming, which has necessitated the determination of the nature and manner of occurrence of the organic matter in these sediments.

C. M. Bouton, Pittsburgh Experiment Station, United States Bureau of Mines, has studied thermo-conductivity of coal. This work may have a bearing on earth temperatures, as the studies deal with coal in place.

W. W. Bowie, United States Coast and Geodetic Survey, Washington, D.C., has specialized on the theory and demonstration of isostasy.

Wilmot H. Bradley, United States Geological Survey, Washington, D.C., is studying the origin and occurrence of oil shale, and its relation to the origin and occurrence of petroleum.

Dr. Louis Brand, department of mathematics, Engineering College, University of Cincinnati, Cincinnati, Ohio, is studying the mathematical theory of elasticity in all its applications to the deformation of solids, with special reference to geologic problems.

Professor E. B. Branson, University of Missouri, Columbia, Missouri, has studied the Devonian black shales of Missouri to determine the source of carbon content and the origin of the shales and associated sandstones and limestones. He is also studying the Mancos shale of New Mexico to determine results of intrusives, places of oil origin, and origin of sediments.

Professor P. W. Bridgeman, University Museum, Cambridge, Massachusetts, is studying deformation of rocks, and determination of coefficients of friction between rocks and comparable bodies.

Professor Freeman F. Burr, St. Lawrence University, Canton, New York, has nothing in progress but is "ready and willing to co-operate with the Council in any way that may be suggested."

Professor Walter H. Bucher, University of Cincinnati, Cincinnati, Ohio, is particularly interested in the physical principles involved in deformation of solids, and in interpretation of rock structure.

Professor Charles W. Cook, department of geology, University of Michigan, Ann Arbor, Michigan, has experimented to determine the capillary relationships of oil and water.

Dr. C. S. Corbett, University of Kansas, Lawrence, Kansas is making a study of petrographic characters of deep formations encountered in drilling in eastern Kansas.

Professor George H. Chadwick, University of Rochester, Rochester, New York, has been tracing the Upper Devonian of New York, which includes black shales and oil sands. This stratigraphic and structural work may furnish information regarding both source and reservoir rocks.

DR. R. T. CHAMBERLIN, University of Chicago, Chicago, Illinois, specializes on structural geology, and his work on isostasy, deformation of rocks, and the origin and development of deformation in various regions is important to the oil geologist.

E. R. CUMINGS, department of geology, Indiana University, Bloomington, Indiana, has studied micropaleontology of Ordovician, Silurian, and Devonian rocks, particularly in Ohio, Indiana, and Kentucky; he has specialized on bryozoa. Slides and illustrations of type fossils are available.

PROFESSOR C. L. DAKE, Missouri School of Mines, Rolla, Missouri, is studying sources of Pennsylvanian sediments in the Ozarks, and the tectonic history of the Ozarks.

PROFESSOR R. A. DALY, University Museum, Cambridge, Massachusetts, is interested in studies on earth temperatures, isostasy, and sedimentary petrology.

N. H. DARTON, United States Geological Survey, Washington, D.C., is interested in studies in the structural history of a region.

T. DAVIS, department of geology, Columbia University, New York City, has made a compilation study of geology and oil production in South American oil fields.

PROFESSOR DUNLAP, Missouri School of Mines, Rolla, Missouri, has studied changes in composition of water due to contact with hydro-carbons, and also problems that bear on the refining of petroleum.

PROFESSOR W. H. EMMONS, University of Minnesota, Minneapolis, Minnesota, is interested in all problems of oil geology, and has directed experimental work by Mr. H. E. LaTendresse on flow of oil by head.

E. THEODORE ERICKSON, United States Geological Survey, Washington, D.C., is studying chemical problems bearing on the genesis of petroleum and oil shale, and also alterations in composition of oil due to contact with water.

A. E. FATH, United States Geological Survey, Washington, D.C., is making studies of rock deformation.

W. H. FULWEILER, United Gas Improvement Company, Philadelphia, Pennsylvania, has worked on means of identifying oils by their chemical and physical properties.

JAMES GILLULY, United States Geological Survey, Washington, D.C., is carrying on some studies in sedimentary petrology.

PROFESSOR L. C. GLENN, Vanderbilt University, Nashville, Tennessee, has conducted studies bearing on origin and present composition of sediments that contain bituminous and carbonaceous matter, the nature of the material when first deposited and subsequent changes; studies in sedimentary petrology; studies in physiographic expression of structural forms most important in petroleum geology; and studies in structural history of a region.

M. I. GOLDMAN, United States Geological Survey, Washington, D.C., specializes on petrography of sediments, and is now studying the nature and origin of salt dome cap rocks.

PROFESSOR L. C. GRATON, Foxcroft Building, Cambridge, Massachusetts, has studied the deposition of calcite, barite, gypsum, and similar minerals in nature, and the secondary deposition of cement by these minerals.

DR. E. P. HARDING, department of geology, University of Minnesota, Minneapolis, Minnesota, has worked on the chemical composition of oil.

G. HAWKINS, department of geology, Columbia University, New York City, has studied Mexican Tertiary foraminifera. This study was directed particularly to application in connection with petroleum-bearing formations.

K. C. HEALD, United States Geological Survey, Washington, D.C., is studying characteristics of source beds of petroleum; the structural control of oil accumulation and occurrence of oil in red beds and in formations of known continental origin.

M. D. HERSEY, Pittsburgh Experiment Station, United States Bureau of Mines, has been perfecting an aneroid barometer free from "lag" for surveying, has designed apparatus for studying migration of fluids through porous bodies, and has studied the viscosity of oil under high temperature and pressure.

D. F. HEWETT, United States Geological Survey, Washington, D.C., has studied rock deformation, and the regional structural histories.

PROFESSOR R. J. HOLDEN, Virginia Polytechnic Institution, Blacksburg, Virginia, has been studying both the petrography and the paleontology of the Tertiary and Cretaceous in northeast Louisiana.

PROFESSOR J. E. HYDE, Western Reserve University, Cleveland, Ohio, has been working on the structural history of northeastern Ohio and has done some incidental work on micropaleontology.

PROFESSOR ROBERT S. HYER, Southern Methodist University, Dallas, Texas, has studied the physical states of oil and gas in oil wells.

PROFESSOR E. C. JEFFREYS, University Museum, Cambridge, Massachusetts, has studied the origin and composition of sediments that contain bituminous and carbonaceous matter.

PROFESSOR F. C. JONES, University of Nevada, Reno, Nevada, has done some work on the origin of petroleum, and particularly with the genetic relation between saline water and origin of oil.

DR. W. F. JONES, Massachusetts Institute of Technology, Cambridge, Massachusetts, is interested in work on isostasy, application of descriptive geometry and trigonometry to solution of problems of faulting and folding, composition of sediments that contain bituminous and carbonaceous matter, deformation of rocks under load, studies in physiographic expression of structural forms, and studies in structural history of a region.

W. S. W. KEW, 901 South Norton Ave., Los Angeles, California, is interested in studies in micropaleontology and studies in regional structure.

PROFESSOR J. F. KING, Thompson Chemical Laboratory, Williams College, Williamstown, Massachusetts, is interested in vapor-pressure studies that might be applied to oil-field problems, such as the genesis of certain of the vein hydrocarbons, asphalt deposits, etc., and that should also have a bearing on power of gas to transport oil, water, etc.

PROFESSOR R. S. KNAPPEN, University of Kansas, Lawrence, Kansas, is making a study of the paleogeography of the Pennsylvanian in Kansas with particular reference to conditions of sedimentation.

PROFESSOR HENRY E. LANE, department of physics, University of Rochester, Rochester, New York, has no projects under way, but is sufficiently interested to undertake phases of this work.

EUGENE H. LESLIE, department of chemical engineering, University of Michigan, Ann Arbor, Michigan, is interested in chemical and physical properties of oil as they occur in nature, and researches bearing on their genesis and postgenetic changes.

PROFESSOR W. N. LOGAN, State Geologist, Indianapolis, Indiana, in cooperation with J. R. Reeves has studied the structural history of southwestern Indiana.

PROFESSOR C. R. LONGWELL, Yale University, New Haven, Connecticut. Deformation of rocks, particularly under load.

HENRY MCQUEEN, University of Missouri, Columbia, Missouri, is working on migration of oil through various types of sandstones and sands.

DR. M. G. MEHL, University of Missouri, Columbia, Missouri, has studied genetic relation between compacting of sediments and oil-field structures; climatic conditions and oil accumulation; and land distribution and oil accumulation.

MERL. H. MEIGHN, department of chemical engineering, Columbia University, New York City, has studied the occurrence of phenols in lower temperature coal tars.

A. F. MELCHER, United States Geological Survey, Washington, D.C., has specialized on study of porosity and permeability of oil sands.

PROFESSOR RAYMOND C. MOORE, University of Kansas, Lawrence, Kansas, is making studies in the origin of oil-bearing beds in the Pennsylvanian of Utah, Arizona, Colorado, New Mexico, and midcontinent; subsurface correlation of Kansas formations; studies of buried crystalline rocks of Kansas and adjoining states, occurrence of oil in Mesozoic rocks of the Colorado plateau; and regional structural studies.

GAIL F. MOULTON, University of South Dakota, Vermilion, South Dakota, has been experimenting with the reduction by petroleum of ferric oxide pigment in sandstones.

PROFESSOR P. E. RAYMOND, University Museum, Cambridge, Massachusetts, is interested in studies relating to structural histories of large areas.

DR. R. D. REED, Stanford University, California, is working on correlation by means of occurrences of heavy minerals in sediments. He has had some success in short range correlations.

FRANK REEVES is studying relations between ground water and also the mode of formation of certain peculiar types of faulted anticlines.

DR. J. R. REEVES, department of geology, Indiana University, Bloomington, Indiana, has for three years been studying oil shales of Indiana and Kentucky and geologically related shales. The work includes distribution origin, microscopic study of organic and inorganic composition, chemical analysis, physical characteristics, yield of oil, composition of oil, and relation between fixed carbon, volatile matter, nitrogen, and oil yield.

In co-operation with Professor W. N. Logan he has studied the structural history of southwestern Indiana.

PROFESSOR R. E. RETTGER, Cornell University, Ithaca, New York, is studying criteria to permit distinguishing between contemporaneous- and hard-rock deformation.

C. S. ROSS, United States Geological Survey, Washington, D.C., has been making some studies in sedimentary petrology.

PAUL V. ROUNDY, United States Geological Survey, Washington, D.C., has specialized on Carboniferous micropaleontology.

W. W. RUBEY, United States Geological Survey, Washington, D.C., is studying the origin and significance of faulted monoclines.

DR. W. F. SEYER, department of chemistry, University of British Columbia, Vancouver, Canada, has investigated the tar sands of northern Alberta, and studied the nature of the hydrocarbons present in the asphalt.

J. L. SHERRICK, Pittsburgh Experiment Station, United States Bureau of Mines, Pittsburgh, Pennsylvania, has studied the products of detonation of explosives, which may have an application in studies on changes in composition of water due to contact with hydrocarbons, since some of the experiments indicate that methane may be formed in the Bichel gage from carbon monoxide and hydrogen produced.

PROFESSOR J. H. SHIDELER, Oxford, Ohio, has studied bryozoa and ostracoda up to Mississippian, although he has specialized on the Ordovician.

PROFESSOR ELLIS W. SHULER, Southern Methodist University, Dallas, Texas, has conducted studies in micropaleontology and in sedimentary petrology.

JOHN C. STAUFFER, department of chemical engineering, Columbia University, New York City, has studied the nitrogenous constituents in oil from the Green River shale.

OTTOMAR G. STRIETER, department of chemical engineering, Columbia University, New York City, has studied the composition of asphalt.

PROFESSOR W. A. TARR, University of Missouri, Columbia, Missouri, has experimented with migration of oil under high pressure.

W. T. THOM, JR., United States Geological Survey, Washington, has made studies in structural history of a region.

PROFESSOR W. H. TWENHOFEL, Science Hall, University of Wisconsin, Madison, Wisconsin, has studied criteria for distinguishing between contemporaneous- and hard-rock deformation.

PROFESSOR J. A. UDDEN, University of Texas, Austin, Texas, is a pioneer in the application of micropaleontology to problems of petroleum geology.

DR. E. O. ULRICH, United States National Museum, Washington, D.C., is an authority on micropaleontology, and particularly on Paleozoic forms.

DR. C. E. VAN ORSTRAND, United States Geological Survey, Washington, D.C., has studied movements of fluids through capillary openings. He has also studied methods for determining porosity of ceramic materials and similar dry substances.

PROFESSOR CHARLES WATKEYS, University of Rochester, Rochester, New York, has studied the mathematics of stratigraphic and fault movements.

DR. THOMAS L. WATSON, Virginia Geological Survey, Charlottesville, Virginia, is interested in stratigraphic problems relating to possible occurrence of oil in Virginia, and also in relation between carbon ratios of coal and presence of petroleum.

R. C. WELLS, United States Geological Survey, Washington, D.C., deposition of calcite, barite, gypsum, and similar minerals in nature and secondary deposition of cement by these minerals. Changes in composition of water due to contact with hydrocarbons.

DAVID WHITE, United States Geological Survey, Washington, D.C., is investigating origin of oil, origin of oil shales, and character of the embedded pyrobitumen, micropaleontology, isostasy.

S. WISSLER, department of geology, Columbia University, New York City, has studied conditions under which sources of oil are deposited.

Consideration of the topics listed on the questionnaire permits the following tabulation of men working on each problem:

Chemical and physical properties of oils as they occur in nature, and researches bearing on their genesis and postgenetic changes: W. E. ALLEN, E. THEODORE ERICKSON, W. H. FULWEILER, E. P. HARDING, EUGENE H. LESLIE, W. F. SEYER, JOHN C. STAUFFER, OTTOMAR G. STRIETER, and DAVID WHITE.

Microscopic study of crude oils: No one.

Laws controlling migration of fluids through heavy bodies, particularly under heavy pressure: W. H. EMMONS, HENRY MCQUEEN, A. F. MELCHER, W. A. TARR.

Studies of porosities of rocks: A. F. MELCHER.

Diffusion of oil through water and water through oil. Diffusion of gas through water and oil: No one.

Determination of coefficients of friction between rocks or comparable bodies under varying conditions of temperature and pressure: No one.

Earth temperatures: C. M. BOUTON, R. A. DALY, A. C. LANE, C. E. VAN ORSTRAND.

Heat of chemical reactions, and of granular and molecular friction under movement stresses, and rates of heat radiation. No one.

Capillarity, particularly between two liquids in contact: CHAS. W. COOK, M. D. HERSEY, A. F. MELCHER, EDWARD W. WASHBURN.

Electrical prospecting: ARTHUR R. BAUDER.

Sound ranging, where sound is transmitted through rock. No one.

Deposition of calcite, barite, gypsum, and similar minerals in nature. Secondary deposition of cement by these minerals: L. C. GRATON, R. A. VAN MILLS, ROGER C. WELLS.

Changes in composition of water due to contact with hydrocarbons: DUNLAP, E. THEODORE ERICKSON, ROGER C. WELLS.

Isostasy: W. W. BOWIE, R. T. CHAMBERLIN, R. A. DALY, W. F. JONES, DAVID WHITE.

Determination of fixed carbon in carbonaceous shales and bituminous limestones: No one.

Effect of carbonaceous and bituminous matter on the natural pigments that give rocks their color: GAIL F. MOULTON.

Application of descriptive geometry and trigonometry to solution of problems of faulting and folding, such as determination of displacement of faults, measurement of stratigraphic sections, etc.: D. F. HEWETT, W. F. JONES, C. R. LONGWELL, CHARLES WATKEYS.

Development of new methods and instruments for mapping: M. D. HERSEY.

Studies bearing upon the origin and present composition of sediments that contain bituminous and carbonaceous matter, the nature of the carbonaceous material when first deposited, and the subsequent changes in the latter: W. E. ALLEN, RUFUS M. BAGG, C. A. BONINE, WILMOT H. BRADLEY, E. B. BRANSON, GEORGE H. CHADWICK, C. L. DAKE, E. THEODORE ERICKSON, L. C. GLENN, K. C. HEALD, E. C. JEFFREYS, W. F. JONES, R. S. KNAPPEN, R. C. MOORE, J. R. REEVES, DAVID WHITE, S. WISSLER.

Deformation of rocks, particularly under load. Any experiment or other research that would throw light on the way rocks bend and break, and the nature of the forces and the conditions under which bending or breaking takes place: P. W. BRIDGEMAN, LOUIS BRAND, WALTER H. BUCHER, R. T. CHAMBERLIN, A. E. FATH, D. F. HEWETT, W. F. JONES, C. R. LONGWELL, FRANK REEVES, R. E. RETTGER.

Observation and experiments in compression (with reduction of volume) and shrinkage of sedimentary rocks: No one.

Studies in sedimentary petrology, particularly such as may aid in the correlation of formations through examination of such material as may be gotten from drills: identification of fault phenomena through study of drill cuttings; recognition of unconformities; recognition of incipient metamorphism: HAROLD L. ALLING, C. S. CORBETT, M. I. GOLDMAN, W. H. TWENHOFEL, J. A. UDDEN.

Studies in micropaleontology: RUFUS M. BAGG, R. S. BASSLER, J. E. HYDE, P. V. ROUNDY, J. H. SHIDELER, ELLIS W. SHULER, J. A. UDDEN, E. O. ULRICH, DAVID WHITE, E. R. CUMINGS.

Studies in physiographic expression of structural forms most important in petroleum geology: L. C. GLENN, W. F. JONES.

Studies in structural history of a region: N. H. DARTON, A. E. FATH, L. C. GLENN, K. C. HEALD, J. E. HYDE, W. F. JONES, W. N. LOGAN, R. C. MOORE, P. E. RAYMOND, J. R. REEVES, W. T. THOM, JR.

THE USE OF FORAMINIFERA IN GEOLOGIC CORRELATION

JOSEPH A. CUSHMAN
Sharon, Massachusetts

Due to a combination of circumstances, the foraminifera hold a unique position as regards geologic correlation. Their value in spite of their ever increasing use has been occasionally questioned. As the group is becoming so widely used by many workers, Mr. Max W. Ball, president of the American Association of Petroleum Geologists, has asked me to prepare this paper.

The foraminifera are essentially marine. A few species live in brackish water, but no typical foraminifera are known from fresh waters. As a rule, they secrete a calcareous test or form one of foreign material, such as sand grains, etc. These tests are easily preserved as fossils. At the present time and through the Tertiary and Cretaceous at least they are the most abundant marine animals. In the present oceans they form the mass of the oozes which make up most of the floor of the great ocean basins. In the tropics even in shoal water they are very abundant, usually making up a large proportion of the so-called "coral sand" of warm waters. During the Cretaceous and Tertiary they have formed limestones thousands of feet thick, a map of which corresponds amazingly with the areas from which Tertiary and Cretaceous oil fields are producing today. Most of the species are microscopic, so the number of individuals is beyond computation.

Throughout the Tertiary and Cretaceous very few strictly marine deposits are without foraminifera. Beach gravels and sands often do not have them, but as a rule they have few organisms of any kind. Marine clays, sands, and marls often abound in them. The small size, and it is a fair figure to say that the average diameter is around a millimeter, is one of the great factors in their use. Any well, whatever its diameter, drilled through marine strata of Cretaceous or Tertiary deposits is sure to encounter them. I have

found at times a hundred species in a cubic inch of Tertiary or Cretaceous clays. The number of individual specimens in such an amount is often very large. Drilling operations, whether with rotary or cable tools, do not destroy them. Other groups of organisms, such as the mollusks, crustaceans, or corals are usually destroyed or broken beyond recognition. In cases where small specimens of these groups escape, they are usually immature and specifically unidentifiable. The two groups, bryozoans and ostracods, sometimes have the value of small size, but not usually great numbers nor almost universal occurrence in marine strata. The foraminifera then form an ideal group from physical characters for geologic correlation, due to their small size escaping the destructive tendencies of drilling, great numbers making some of them usually present even in very small samples and their very general distribution in the marine strata of Cretaceous and Tertiary age. It will, I think, be agreed by all workers that from the physical characters alone they should form ideal fossils for correlation.

We may divide geologic correlation into two main divisions according to the purposes for which the work is done. For convenience these may be termed scientific and practical, although neither term is a good one, for the most scientific work should give practical results and practical results should be exact.

For scientific correlation may be taken the work of individuals or surveys who are interested in what may be called geologic problems as such. Correlations are made for the purpose of geologic mapping or to prove or disprove theories of geologic processes. These do not take into consideration the exploitation of any particular content of the strata themselves, for their purpose is entirely different. The results obtained may often be used for these purposes, however.

In determining the age of strata encountered in mapping a new area, its relations to other known formations above or below give its general age. Unless the particular area is far removed from those in which geologic work has been done, rather definite results can readily be obtained. One of the old tests was that of mathematical percentages of the living and extinct species or genera, usually of mollusca contained in a given sample. As more detailed work has

been done, the percentages given by Lyell have gradually been changed, for with increased systematic work many new species have been made, and workers even in the same group very often do not agree with one another in systematic identifications. Moreover, different groups of organisms do not show the same percentages, as evolution has differed in its rate in different groups. The mammals certainly would show very different figures if Eocene species were compared with present-day ones, from what is shown by the bryozoans or crustacea.

Assemblages with dominant species or genera do, however, characterize all the main Cretaceous and Tertiary formations, great and small. An abundance of *Exogyra* alone would place a sample of rock as pre-Tertiary. Certain species of *Pecten*, *Turritella* or *Orthophragmina* would place an outcrop in its proper relation to other outcrops of the same age elsewhere. Most long-range species are being gradually split into many species with short ranges. In this same way the specialist in foraminifera is able to recognize by the assemblage of foraminiferal species and genera the relative age of the sample submitted to him for study. For the purposes outlined above, studies of this sort are of sufficient detail for surface geologic mapping or for the identification of formations for various uses.

To turn to what may be the practical side of correlation, a very different attitude must at once be taken. The work in correlation for petroleum uses must often be of a very exact character. It is not usually a matter of the age of a certain formation, but just where in one well section does a certain sample from another well in the same field correlate? Are the beds becoming higher or lower? What is the angle of dip of the producing sand between two wells? In such cases no abstract method of age determination will do, but there must be a very careful and detailed examination of the contained specimens. The occurrence of abundant and well-known Cretaceous foraminifera may very definitely tell the worker that he is not in the Cretaceous Austin chalk at all, but in the Miocene Flemming. The abundance of a certain species of *Cristellaria*, with an equally striking *Rotalia* and *Nodosaria*, may indicate that this is a definite zone of Midway Eocene. A peculiarly pyritized

group of *Allomorphina* and *Chilostomella* will instantly fix the position of another sample, and so on throughout the section. The worker is not worried as to what the percentage of living species may be or the exact vertical range of a long-lived species in his sample if he can find the exact point at which occurs the contact between materials bearing two distinctive faunas, whose position in the section is already known to him. Then he can say that the strata between the two wells are rising and the oil possibilities are thereby measurably increased in certain directions, or that water sands should be cased off at certain points. It is this practical side which gives to the petroleum industry such far-reaching results from the use of the foraminifera.

To obtain such results with accuracy that is dependable to a high degree is not an easy matter. The group of the foraminifera, like all other things which are desirable, exacts its price toll. It is not an easy group with which to work. A short history of work on the group will explain this in the best way.

The worker on the foraminifera has, like all other workers, a certain legacy from the past. D'Orbigny's classic work, giving one of the earlier classifications, was published almost 100 years ago and included a great deal of the earlier work. In the last 100 years it is difficult to estimate the great amount of literature dealing with the group. Some idea of it may be obtained from the simple statement that Sherborn's *Bibliography of the Foraminifera*, published in 1888, contains a list of nearly 2,000 books and papers published to that date, which are all or in part devoted to the foraminifera. In the 35 years since that date a very large number of titles have been published, so that the number today is easily double Sherborn's list.

Sherborn's index to the genera and species of the foraminifera to 1888 gives nearly 1,000 generic names, and under *Cristellaria* alone well over 500 specific names. The number of specific names used to that date runs into many thousands, and in the last 35 years this has been greatly increased. This vast literature scattered through many publications and in numerous languages can be obtained only at a few of the great library centers. For any one person to become at all familiar with the literature, even if it be accessible, is the task of a lifetime. This is one of the great handicaps to scientific work on the group.

Another inheritance from the past is the attitude of many workers, especially the group of British workers; W. B. Carpenter and his students, W. K. Parker, and T. Rupert Jones. They held that the group, being protozoa, and being animals of low organization, were extremely variable, and that, such being the case, the ordinary terms of systematic treatment could not be applied to them. It has taken a long time to shake off even in some measure this early interpretation, which, like all false accusations, clings tenaciously. At the present time the group as a whole is coming to a surer place in geologic work, but only as a result of a different attitude toward them by students of the foraminifera. I have been accused by workers on the group with being extremely radical in the way I have split forms into genera and species, and yet a paper read before this meeting last year by Dr. Vaughan[1] seemed to prove that I had been ultraconservative in this regard compared with workers on other groups of American fossils. A distinction was there made between the "larger" and "smaller" foraminifera, and the larger foraminifera were accorded a place of honor with the mollusca, bryozoa, and corals, as far as correlation purposes are concerned. This distinction between larger and smaller foraminifera is an unfortunate one, and one for which I am entirely to blame, having published two papers on the foraminifera of the Canal Zone some years ago under these headings. These so-called "larger" foraminifera are mostly of the family Nummulitidae. Even the genera involved include many small species which are equally valuable for correlation purposes. This comparison was taken from my own work; and I may therefore feel complimented, as the group has long been considered a very variable one, especially genera such as *Operculina* and *Lepidocyclina*. If these larger species are admittedly of excellent character as regards correlation, what is the matter with the smaller ones?

One difficulty which is probably greatest is that of small size. With the large species it is possible to treat them as mollusks or echini. They can be sorted by hand into trays and comparisons easily made from one specimen to another. With small species, mechanical handling becomes much more difficult. Specimens

[1] *Proc. Amer. Petr. Geol.* (1923), pp. 517–31.

must be mounted for microscopic study. It is not easy to carry in mind visual images while transference of slides takes place and a series of specimens compared with the original. The characters are much finer, sculpture more easily obliterated, and form less easily carried in the mind. Then, again, it is not so easy to study series of specimens from different localities or wells to make sure what the limits of variation may be. The larger forms can be seen with the unaided eye and characters easily studied. Many species lack external ornamentation, and are therefore to that extent difficult to distinguish.

When small species have very definite characters and due regard is given to details, I do not hesitate to predict that they will be found equally valuable with the larger species and with other groups of organisms. The amount of work yet to be done is very great, and there are hundreds of species of these smaller forms for every one of the larger ones. The coming of new workers into this field is therefore a very hopeful sign for the accomplishment of these ends.

When the new worker on the foraminifera looks for a name for a particular species, he is apt to be entirely bewildered by the multiplicity of forms that appear under one name. This is very unfortunate, and is one of the legacies he must recognize as having come to him from the past. The only scientific solution is to examine the original type specimens, a process which, for most workers, is an impossibility. The impression is fixed that great variability is the rule, and there is a consequent let-down in attitude, which often leads to very inexact work.

It seems to me that the one basis of work on the side of petroleum problems is for the worker to know in detail his type section. Then, with this as a basis, it is possible to work out into broader problems and into other areas. This must of necessity take much time and patience.

One of the main features which has made a tendency to question the real value of the foraminifera in correlation is that of totally unprepared workers. Petroleum problems have to be solved quickly or often not at all. The number of persons who have had any considerable training in the group is very small, and those few have certainly been making good to a remarkable degree in their work.

Then, again, in the last two or three years especially, the demand for workers on this group has greatly increased, largely through the knowledge of what has been done by the few. As a result, many wholly untrained or very superficially trained persons have started work, many of them temperamentally unfitted for the patient, exact work that such a study involves. On the other side has been often the demand from the employer to accomplish the impossible. Failure from either cause has cast reflections on the work as a whole. A better understanding of the results possible to be obtained should be in the minds of both workers and employers.

For the best results, therefore, the worker on the foraminifera should have as long an acquaintance with the group as possible before starting his economic work. He should realize the difficulties of the task ahead of him in attempting close correlations in any area until his type section is thoroughly studied. He should not be stampeded into giving determinations until he is sure of his own results and that his data are adequate. Checks from the point of view of lithology, which should go hand in hand with the work on the foraminifera, should constantly be welcomed.

When well-trained workers attack the problems, it will be found that the foraminifera will be the means of discovering many fields not now suspected and making accurate subsurface maps as drilling progresses. In the right hands the foraminifera are one of the greatest aids in the geology of petroleum.

PRELIMINARY REPORT ON WATER CONDITIONS IN THE FIRST WALL CREEK SAND, SALT CREEK OIL FIELD, WYOMING

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The present report embodies the results of studies made by the writer in the Salt Creek oil field, Natrona County, Wyoming, during the latter part of 1922 and up to May, 1923. Although a great amount of work in connection with this study remains to be done, enough progress has been made to justify the announcement of certain facts and characteristics pertaining to water conditions found in the First Wall Creek sand.

In the Salt Creek field at the present time there are two known producing horizons, the First and Second Wall Creek sands. These two sandstones belong to the Colorado group of the Upper Cretacous series and are further considered as a portion of the Frontier formation found in other parts of Wyoming. The First Wall Creek has an average thickness of about 136 feet, being somewhat thicker in the southern end of the field than it is in the northern part. This sand was the discovery sand of the field and now has a productive area of approximately 3,000 acres, with 133 wells drilled. Production in this sand has ranged all the way from 5 to 4,000 barrels of oil per day, the size of the well depending upon several different factors such as structural position, proximity to faulted areas, and texture of the sand itself.

The other productive sand, which is the field's most prolific producer, is called "the Second Wall Creek sand." It has an average thickness of 60 feet, and the interval between the top of the First and the top of the Second is approximately 395 feet. The average depth to the First Wall Creek is about 1,200 feet, and to the Second, 1,600 feet in the area on top of the structure. The Second sand gives the field a productive area of about 22,000 acres. Wells in this sand have varied in initial production from

30 to 13,000 barrels. It is in the drilling of the Second sand wells that most of the data governing the First sand have been secured for this paper, due to the fact that wells intended for the deeper sand are drilled to a point 225 feet below the top of the First, and casing set there and cemented. This gives the driller and the engineer an opportunity to observe the texture of the sand in drilling through, to notice the depth at which water is encountered, and to take any other notes desirable.

Operators in the Salt Creek field with nothing but Second sand wells are particularly fortunate in having subsurface conditions so ideal that very little or no trouble at all may be anticipated from underground waters, providing a successful shut-off of the First sand is secured by cementing. Even then it seems that quite frequently a simple, tight-formation shut-off would suffice when the upper sand is found barren of either oil or water. Only one operator in the field, the Midwest Refining Company, has to contend with repair work and the shutting off of bottom water in the First sand. This is due to the fact that this company owns or controls all the First sand productive territory which lies on top of the structure with its lower limit following roughly the 3,650-foot (sea-level) contour.

Assuming that C. H. Wegemann, in his report on the Salt Creek field,[1] has correctly shown the position of the productive limit of the First sand in 1915 as following the structure between the 3,500- and 3,600-foot contours, it is seen by referring to the accompanying map, showing the present productive limit, that there has been considerable water encroachment. This amounts to approximately 100–150 feet structurally and about one-quarter of a mile on the surface at the eastern side of the area. Since the eastern flank of the Salt Creek anticline is an area of smaller dips, and because the majority of the First sand wells are located on this side of the structure, the encroachment of water here has been considerably more than on the west. Horizontally, the distance covered by encroaching water on the west has been about 800 feet.

With the exception of two or three First sand wells which have been repaired for bottom water and cemented in the last three

[1] "The Salt Creek Oil Field," *U. S. Geol. Survey, Bull. 670*, 1918.

years, practically no work had been undertaken in that connection until the winter and spring of 1922 and 1923. At this time it was found necessary to abandon well No. 28, in the SW. ¼, Sec. 13, T. 40 N., R. 79 W., because it had gone to water. This well was drilled in August, 1912, and came in at 2,000 barrels. Twelve other wells, most of them located on state and patented land, have had cement plugs placed in the bottom of the hole to shut off water. The big majority of First sand wells were drilled by 1916, the first one having been drilled in 1908. Thus it is seen that very little trouble due to water encroachment had been experienced prior to the winter of 1922–23, when only one well had been abandoned. Some of the group of wells on the SW. ¼, Sec. 13, T. 40 N., R. 79 W., produced a little water from the first, so the limit in that direction was defined at once. At present these wells are all either dead or producing large quantities of water. It is practically certain that the dead wells in this quarter-section have been drowned out temporarily by bottom water, and a program of repair work and cementing back has now been started.

Very few government-lease wells are making water, and most of the repair work is more necessary on the state and patented land, due to the fact that these leases were the first to be drilled extensively. The close grouping of the wells in these sections is partially responsible for the drawing in of water, which causes the so-called "water line" to be irregular in contour in this vicinity. The state land includes all of Sec. 36, and the E. ½ of Sec. 25; the W. ½ of Secs. 13 and 12 is patented land.

The only First sand wells now pumping are those in Section 13. All others are capable of flowing with a few exceptions. A government well, No. 13, SE ¼, Sec. 22, was filled with 10 feet of cement in March, 1921, to shut off bottom water, and the job was successful. Prior to cementing, 86 per cent of water and emulsion was being produced. After cementing, the amount of water produced was 1.5 per cent of a total production of about 10 barrels a day. This was the second well drilled into the First sand.

In shutting off bottom water in the Salt Creek field, it has been the custom to first clean the hole thoroughly, fill it with water, then place the cement on the bottom with a dump bailer. After the

cement has set a sufficient length of time, the hole is bailed dry and tested. If no oil or gas is present the cement plug is drilled out cautiously until the oil and gas come in. Frequently a small amount of water is encountered again before picking up the gas, but it is considered more economical to contend with a small amount of water and have gas enough to make the well flow, than it is to equip the well for pumping and have no water.

It was found by experience that repair work in shutting off bottom water could be facilitated greatly if it were possible beforehand to know just how much hole should be plugged and what the water level is in each case. In an effort to learn and work out a definite procedure in determining the water level and plugging point in each well, the writer has made this problem more or less a special study, and some conclusions have been reached which will materially help in the work.

In the past it has been the general assumption in the field that the oil-water contact in the sand was a horizontal plane passing through the inclined sand body in such a way that every well drilled farther "up dip" would encounter progressively smaller and smaller amounts of water until the entire sand would be free of water and nothing but oil secured. Below this so-called "water line" nothing was expected but water. As a matter of fact many bulletins and textbooks present this idea in the form of numerous ideal drawings or illustrations demonstrating this condition in an oil sand. Possibly this situation prevails in some fields, but in the Salt Creek field it exists only in a very minor way.

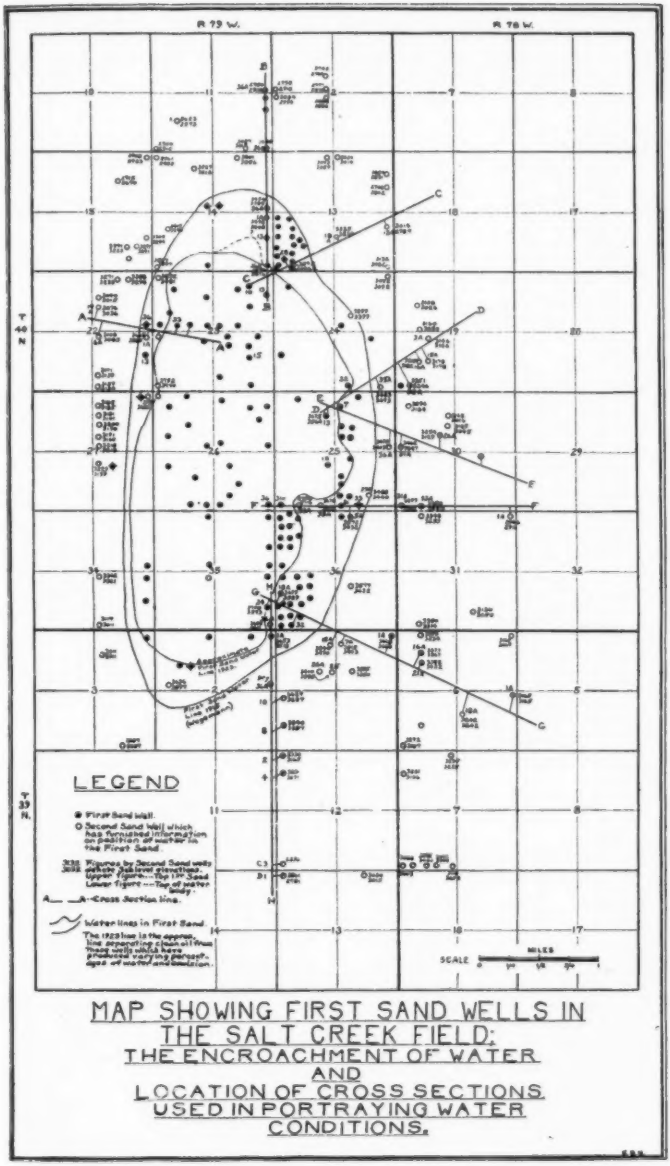
Although the Midwest Refining Company has for some time requested its drillers to report the depth at which water was encountered in the First Wall Creek sand outside its productive limit, no special cognizance was taken of this information in applying it to a practical field problem. In making use of the data a small map of the Salt Creek field was drawn (Fig. 1), showing all the First sand wells, and only those Second sand wells where water was known to have been encountered in the First sand. Beside each well was placed the sea-level elevation of the top of the sand and also the elevation of the point in the sand where water was encountered. Cross-sections were made of eight different parts of the field using

the information given by the wells in the immediate vicinity of the cross-section lines. If not right on a cross-section line, wells were projected into the line along the line of strike. The map and cross-sections show the top and bottom of the First Wall Creek sand and an intermediate line drawn to represent the water contact itself. The dotted portion of the sections represents water. This appears to be the only satisfactory way of showing the true situation which exists.

In referring to the cross-sections, the amount of variation in position which the water body has in the sand may be seen at once. In some cases, such as in Sec. B–B (Fig. 2) and Sec. G–G (Fig. 3), it is found that water is encountered in the upper part of the sand and in a few instances at the very top. Again, as shown in Secs. C–C (Fig. 2), E–E, and H–H (Fig. 3), it is found principally in the lower part of the sand. If the depths in the sand were to be averaged, however, it would be found that, generally speaking, water is not found until the lower two-thirds of the sand is reached. This condition prevails in all parts of the field and is one which must be considered when repair work is done in First Sand wells, or when new wells are drilled in edge territory.

The information relative to the water level will of necessity only be used in this edge area, consisting of the S. ½ of Sec. 14–40–79; SW. ¼ Sec. 13; W. ½ Sec. 24; Sec. 25; W. ½ Sec. 36; SE. ¼ Sec. 35; N. ½ Sec. 2–39–79; NE. ¼ Sec. 3–39–79; E. ½ Sec. 34; E. ½ Sec. 27; E. ½ Sec. 22; and the NW. ¼ Sec. 23. The evidence at hand seems to show that as the oil body is approached in the First sand, the water body gradually lies lower and lower in the bottom of the sand until it is pinched out entirely. In a few instances it seems to rise to a peak and then declines until the bottom of the sand is reached. This is shown particularly in Secs. C–C, E–E, G–G, and H–H. Incidentally this is more pronounced in the cross-sections mentioned in those localities where wells are grouped more closely together. To the writer's belief this is due to "water coning" and is caused by the wells having produced for a long time, drawing the water in as the oil is taken out.

The explanation for the position of water as it is in the First sand is as yet not entirely evident and may be due to variation in


R 79 W.
R 78 W.
T 40 N.
T 39 N.
LEGEND
First Sand Well.
Second Sand Well which has furnished information on position of water in the First Sand.
Figures by Second Sand wells indicate relative elevations. Upper figure—top of the 1st Sand. Lower figure—top of water body.
A—A' Cross Section line.
Water lines in First Sand.
The 1923 line is the approximate line separating clean oil from those wells which have produced varying percentages of water and emulsion.
SCALE
MILES

MAP SHOWING FIRST SAND WELLS IN THE SALT CREEK FIELD: THE ENCROACHMENT OF WATER AND LOCATION OF CROSS SECTIONS USED IN PORTRAYING WATER CONDITIONS.

FIG. 1

porosity, the presence of "shells" or hard streaks in the sand body which may hold the water down, or impervious shale breaks. The driller notices a difference frequently in the way tools work in drilling through the First sand and records hard streaks and shale partings, but so far not enough evidence has been secured which will show a definite relation between these and the water position. Certainly some sand characteristic is responsible, and the writer believes that it is due to a variable shell or hard streak or a shale parting which is either absent or fractured by faulting, allowing the water to occupy the entire sand in those places where water is found in the top of the sand (see Secs. B–B and G–G). The lower part of Sec. B–B is in a highly faulted area. On the other hand, faulting could account for the absence of water in certain areas due to the escape of natural gasses and their evaporative action.[1] The Salt Creek field is extensively faulted, but the cross-sections are too small in scope to permit showing it.

A second sand well, 26-A, on the NW. ¼ of Sec. 1, T. 39 N., R. 79 W., in drilling through the First sand in August, 1922, encountered a strong artesian flow of water when 25 feet in the sand. This flow had such pressure behind it that it blew the tools out of the hole in one instance and flowed over the top of the rig several times during the day. When not flowing in one of these big heads the water gently rolled over the top of the casing. It is thought by some that gas pressure assisted in making this well flow water in such heads, but no free gas was evident. Not one-half mile away, in the NE. ¼ of Sec. 2, Well 36-A encountered no water at all in the First sand. The flow of water in 26-A was cemented off, and the well completed as a Second sand well. An off-set well, No. 25, 440 feet east, however, is being completed as a water well by the Midwest Refining Company, and the big water was found 55 feet in the sand. This well flows gently over the top of the casing, but not in heads. It has a temperature of about 85 degrees F. The top of the sand in this well was found at 1,463. In most of the wells drilled through the First Wall Creek sand outside the productive limit, the hole stands half full of water, and in many cases entirely full by the time the bottom of the sand is reached.

[1] R. Van, A. Mills-Roger, C. Wells, "The Evaporation and Concentration of Waters Associated with Petroleum and Natural Gas," *U. S. Geol. Survey, Bull. 693.*

An examination of the First sand at its outcrop in the Tisdale region, 15 miles northwest of Salt Creek, discloses the fact that it is rather shaly in places, but where there is pure sandstone it is

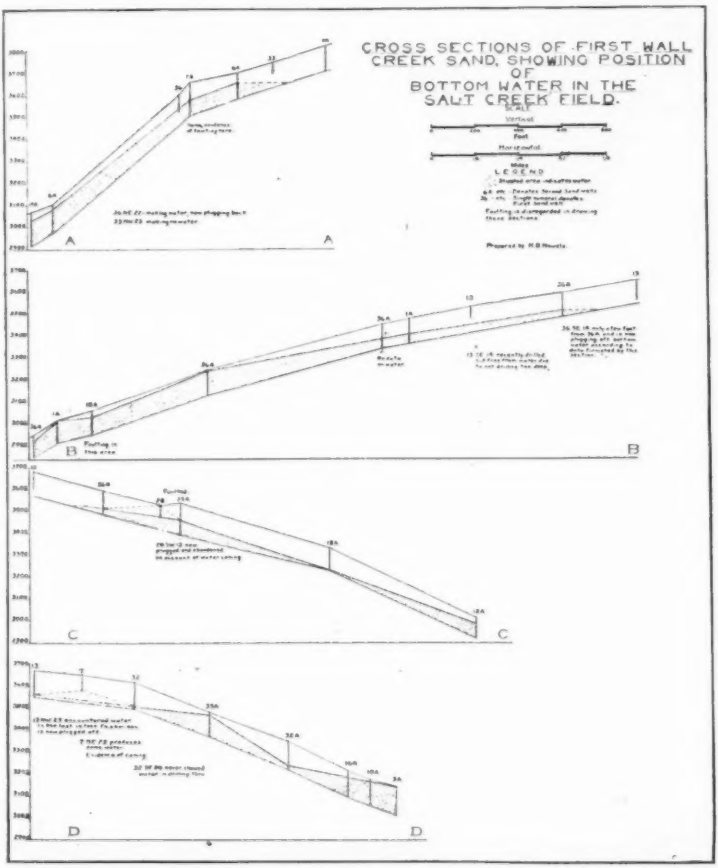


FIG. 2

thinly bedded, with the bedding planes 2 to 4 inches apart. The upper part of the bed seems to be more massive. The writer has observed that a rather consistent hard, ferruginous, con-

cretionary layer about 2 to 3 feet thick occurs 25 to 30 feet from the base of the sandstone bed.

Wegemann[1] says:

> The Wall Creek as reported in wells in the Salt Creek field is about 125 (?) feet in thickness, but as exposed along the east flank of the Powder River dome it appears to be about 100 feet thick. The upper surface of the bed forms a dip slope almost a mile long, and a certain part of it may have been removed by erosion so that the true thickness of the bed may be that recorded in the wells, for because of the peculiar nature of the exposure it is impossible to make an accurate measurement of the bed at the surface. The Wall Creek Sandstone is shaly at its base, the shale occurring as thin lenses interbedded with the sand. About 40 feet above the base is a 10-foot bed of shale, which divides the sandstone into two parts. In color the sandstone is dirty buff. It is medium grained and in many places cross-bedded.

As the writer has previously mentioned, it is entirely possible that this 10-foot bed of shale 40 feet above the base of the sand is present in the Salt Creek field and is responsible for the occurrence of the water principally in the lower part of the sand, separating the dry sand from that which contains water. At any rate there must be some physical barrier in the sand capable of withstanding or separating differential hydrostatic pressures which certainly exist.

In the productive zone, however, the First sand seems to be more or less saturated with oil from top to bottom, although out of a group of 75 wells chosen at random, 47 of them, in order to secure good production, had to be drilled into the sand a distance great enough to have taken them in most instances into the zone occupied by water outside the productive limit. In other words, the average depth into the sand at which water was found in 75 wells was 45 feet, and 47 out of 75 producing oil wells have penetrated the sand a distance greater than this.

This fact is not conclusive, but it tends to show that for some reason or other the lower half or two-thirds of the sand is more capable of holding either oil or water than the upper part. Unfortunately the logs of all the First sand wells make no mention of differences of sand characteristics, except in those wells drilled during the last year or two. What information is available in these shows also

[1] *Op. cit.*, p. 18.

that a considerable penetration of the sand is necessary before any worthwhile production is secured.

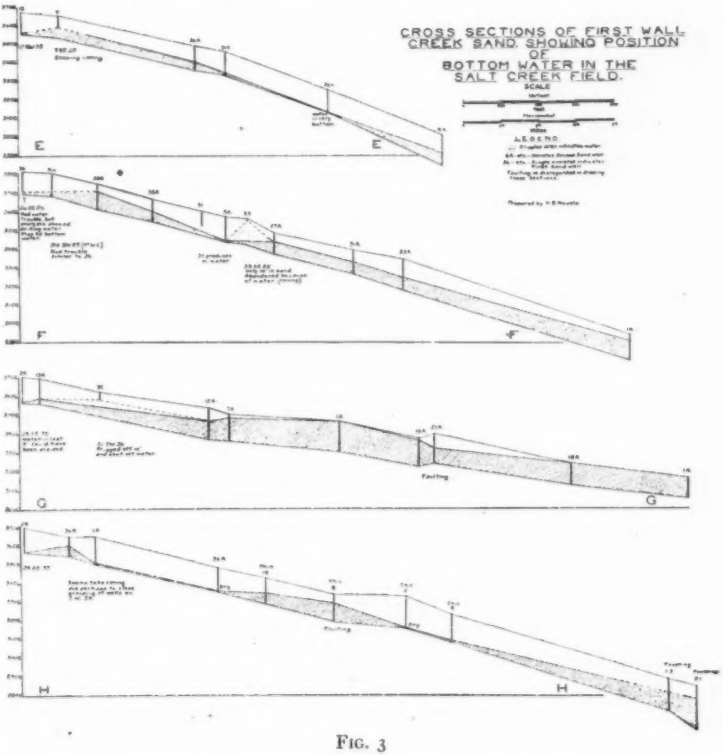


FIG. 3

Some interesting conjectures may be made in this connection relative to the migration of the oil into the sand body.

So far as we know oil, where it is backed by water, always rises up the dip, so that the oil in the crest of any fold is supposedly derived only from the sandstone between that crest and the troughs of the adjoining synclines.[1]

Following out this theory, it is assumed that most of the oil in the Salt Creek anticline has migrated from the east, inasmuch as this

[1] Wegemann, *op. cit.*

region constitutes by far the larger drainage area. Due to surface tension and viscosity, the movement of oil is confined to those channels of migration in which water can circulate. Therefore, it is reasonable to assume that where the sand body contains the smallest amount of water, as denoted by the low-lying water contact, we might expect to find the smallest accumulation of oil and the smallest wells. To some extent this is true, as shown by wells adjacent to Secs. C–C and F–F. Of course there are exceptions, and by the time more data are collected on this subject it may be found that this is not true.

The fact that the definition of the approximate position of the water body in the sand had a practical value was mentioned earlier in this article, and will now be discussed. The use of the cross-sections is of particular advantage in the drilling of new First sand wells, as has been demonstrated during the winter of 1922–23. The last First sand well drilled prior to this time was No. 24 on the NE. ¼, Sec. 35–40–79, in June, 1921. This location was not in edge territory, however, and the possibility of drilling into edge water did not have to be considered. In the drilling of the old First sand wells, particularly on state and patented land, the customary off-set wells on government land were neglected, and it has only been in the last few months that consideration was given to them. As a result, five wells were drilled: No. 13, SE. ¼ 14; No. 32, SE. ¼ 24; No. 13, NW. ¼ 25; No. 12 SW. ¼ 25, and No. 24, SE. ¼ 35. Every one of these wells brought up the question as to how far into the sand it would be advisable to drill without striking water. Drilling depths based on the cross-sections were given the different farm foremen, and in only one instance was the information proved erroneous. This was in the case of Well No. 13, NW. ¼ 25, where it was thought that no water would be found, and where it was picked up in the last ten feet of sand. This well is right on the edge, however, and a control point on the high end of the cross-section was lacking, leaving its possibilities to be anticipated from the behavior of nearby wells. The drilling of this well into water was therefore of value, and we now have an accurate control point for Secs. D–D and E–E.

Well No. 24, on the SE. ¼ Sec. 35, was drilled into water, but through no error of the writer's. The drilling estimate of 110 feet

in the sand was disregarded just to "see what they had," and as a result we have another valuable control point for cross-section work. This well, incidentally, hit the water in the lower 5 feet of sand and shows that the water body is pinching out in a very few feet "up-dip" from that well. This well is shown in cross-sections G–G and H–H, either one of which shows nicely an example of water-coning also, as the wells on the SW. ¼ of Sec. 36 have been producing a long time.

The writer must admit in this connection that the "coning" through the barrier in the First sand above its normal position in any one section, more or less disproves his "shale-break" hypothesis in accounting for the position of the water in the sand, because it is unlikely that water would penetrate a more or less impermeable body such as shale. This fact points rather strongly to the suggestion that the barrier is a hard streak or shell of sand of such low porosity that it takes considerable time for water to penetrate it, and only then under conditions which would only exist in an oil sand where a drilled well would cause a reduction of pressure and cause the fluids to rise and either work their way through or around the barrier.

In furnishing estimates for sand penetration in edge territory a safety factor of 10 to 20 feet is allowed. In other words, where a depth is obtained from the cross-sections, 10 to 20 feet is subtracted from it and this figure given the driller.

As was expected, the five wells previously mentioned as having been recently drilled in edge territory failed to secure flowing production and they were given 60-quart shots of nitro-glycerin, which caused them to flow with initial productions varying from 30 to 90 barrels per day. Gas pressure is not strong, however, and the wells will probably be pumping within a year. There is some doubt as to whether it is advisable to shoot edge wells where there is danger of bringing in water after care has been taken to avoid it in drilling.

In repairing and plugging old wells after they begin showing water-subsurface information is desirable, although "water-coning" must be taken into account when referring to the cross-sections. One procedure which can be taken in this case is to plug up to the

point indicated by the water line in its normal position on either side of the "coning," and then later if additional cement is found necessary it can be placed. This at least gives a target to shoot at and is better than no information at all.

As development in the field continues, more and more information will be available for correcting or adding to the present work on this subject. That which has been accomplished is of a preliminary nature and in all probability just an introduction to subsurface work which will follow in continuing investigations relative to water conditions in the First Wall Creek sand.

It has been suggested that a few wells drilling outside the First sand productive limit suspend operations for a few days when only a short distance in the "dry" zone of the First sand in order to see whether or not any oil production is secured. This will be accomplished as soon as possible and will undoubtedly give further information needed in this study.

EVIDENCES OF SLUMPING PREVIOUS TO CONSOLIDATION IN THE PENNSYLVANIAN OF OKLAHOMA[1]

CLARENCE S. ROSS
U.S. Geological Survey, Washington, D.C.

During the progress of detailed studies of the oil resources of Osage County, Oklahoma, various members of the U. S. Geological Survey had opportunities for observations that throw interesting light on the conditions of sedimentation in northeastern Oklahoma in Pennsylvanian time. There is evidence that the uplift of the Arbuckle Mountains occurred at about the time these beds were laid down, so that the Arbuckle, Ouachita, and possibly the Boston Mountains were contributing detrital material in unusual amount to the sediments being deposited in the embayment to the north and west.[2] The Pennsylvanian of northeastern Oklahoma in general becomes thicker to the south, but in southeastern Osage County there is a very unusual thickening of the beds lying between the Hogshooter and Avant limestones. Alternating beds of sandstone and shale lying between the Hogshooter and Avant limestones have the appearance of the foreset beds of a delta deposit, with a very strong north dip that does not correspond with the gentle northwest dip of the Hogshooter limestone just below. Local steep dips, cross-bedding, ripple marks, impressions of striae caused by dragging twigs or seaweed over soft muds,[3] mud cracks, and impressions of rill marks are evidence of alternating shallow water and shore conditions. Associated with beds showing these phenomena are horizons which are predominantly shale but contain many peculiar gnarled, distorted sandstone masses with markings resembling numerous small step faults. These markings are especially abundant in an area centering around Sec. 36, T. 21 N., R. 11 E., and occur at a horizon about 100 feet above the Hogshooter

[1] Published by the permission of the Director of the United States Geological Survey.

[2] Alex W. McCoy, *Bull. Amer., Assoc. Petroleum Geol.*, Vol. 5 (1921), pp. 541–84.

[3] Sidney, Powers, *Jour. Geol.*, Vol. 29 (1921), pp. 66–80.

limestone, but they have been observed by the writer in many places in southeastern Osage County, and are reported from northern localities in the county by K. C. Heald,[1] of the U. S. Geological Survey.

The horizons containing these "faulted" sandstone masses have a wide lateral extent, and are not confined to lines or zones with a definite strike. The horizons have a limited vertical extent of a few hundred feet, for the limestones and sandstones immediately above and below are entirely undisturbed. This makes it clear that these small "faults" cannot be the result of ordinary faulting or of readjustments due to regional stresses.

Udden[2] has suggested that sandstone blocks with small faults from the Wichita of Texas are the result of slumping in unconsolidated beds. In Osage County, Oklahoma, similar markings appear to be the result of slumping, and it is concluded that the shearing forces developed during slumping produced the faults in partly hardened muds with retention of the impressions of these faults in the interbedded sands. The evidence of this mode of origin is so strong and the relationships are so clear that it seems worth while to describe the occurrence in detail.

The individual sandstone blocks showing the step "faults" usually do not form continuous beds, but are irregular, and more or less isolated lenslike masses of sandstone lying in shale. Some of the faulted masses are nearly flat sandstone flags, but more often they are gnarled, warped, and misshapen. The step faults have been observed with throws up to 5 centimeters, and can be traced along the strike a few feet at most. Usually there is one system of faults, but often there is a second group of faults striking at various angles with the first. Many of the sandstone blocks show fine, sharp faults, but in other blocks they are not sharp and have a blurred appearance or merely show corrugated surfaces. The fault scarps on the two sides of the blocks show that the fault planes are flat and unwarped, and they are usually perpendicular to the strike. Very often the fault lines on the two sides of a slab are not

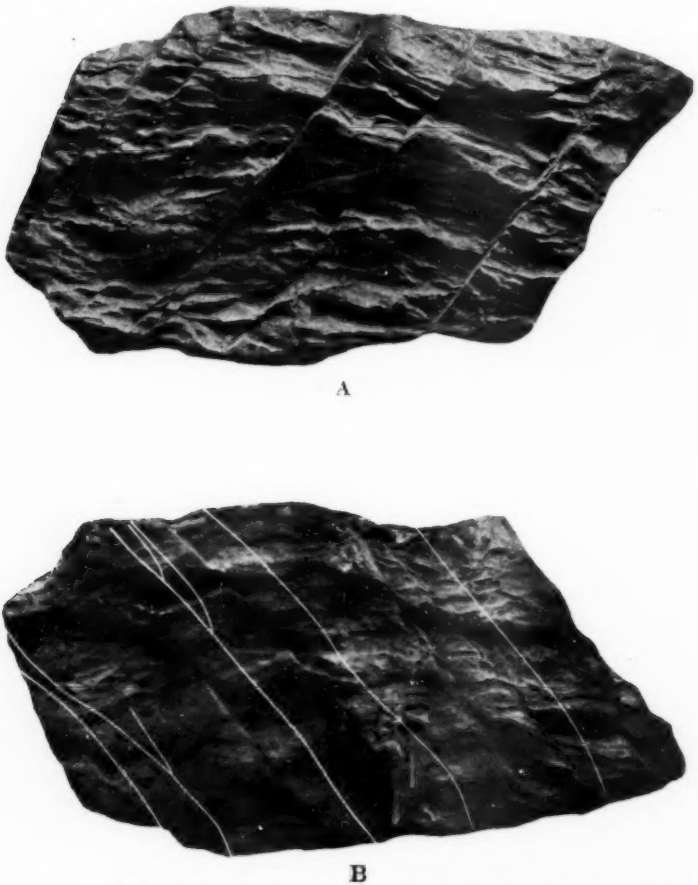
[1] K. C. Heald, Personal communication to the writer.

[2] J. A., Udden, and Drury McN. Phillips, *Univ. of Texas Bull. No. 246*, Pl. XXV, p. 27, 1912.

opposite one another. Sometimes a fault line on one side will not be represented by one on the other side, and the fault lines on the two sides may have a slightly different strike. That is, the faults on the two sides appear not to pass through the sandstone, but each side has a pattern somewhat independent of that on the other side. This leads to the conclusion that the faults on the surface of the sandstone blocks are in fact the impressions in sandstone of faults developed in shale. The difference in pattern of the fault impressions on the two sides of a sandstone slab is well shown in Figure 1, *B*, where the faults on the lower side (Fig. 1, *A*) have been projected through the slab so that they appear as traces on the upper side (Fig. 1, *B*). The fault planes in this slab are perpendicular, yet the fault lines on one side are not cut by traces of the faults on the other side. Figure 2, *B*, represents a block that has been rather sharply faulted. Figure 2, *C*, is not sharply faulted, and it seems evident that the shale was not sufficiently hardened to fault sharply. Figures 1, *A* and *B*, and 2, *A*, appear to have sheared after partial hardening and after more thorough hardening to have been sharply faulted, the two sets of deforming forces having acted at an angle with one another. The surface between the faults is often wrinkled, and this is probably the result of plastic yielding to shearing forces. Slabs have been observed that had beautifully preserved step faults on one side, while the other side was perfectly flat, and in many such specimens minute bedding planes are continuous and undisturbed above the fault scarps, showing conclusively that the sandstone itself was not faulted.

It seems evident that extensive settling or slumping would be likely to occur in muds rapidly deposited on a beach or in a delta. During the movements incident to such readjustment shearing stresses would be developed and there would be plastic yielding if the muds were still soft, and faulting if they had become hardened through drying or partly consolidated by pressure. Partly dried or hardened muds and clays are fairly coherent, while freshly deposited sands are very incoherent and would remain so till cementation had begun. Under the action of shearing forces the sands would yield to stresses in a manner analagous to plastic flow, while the hardened shales would yield by faulting. Thus the

fault plane would not pass sharply through the sand horizon and be duplicated exactly in the shale on the two sides. For this reason



A

B

FIG. 1.—Photograph of the two sides of a sandstone block showing "step fault" with a throw of about ½ inch and a strike slip of ¼ inch. Collected by the writer in Sec. 9, T. 20 N., R. 12 E., Osage County, Oklahoma. Length about 8 inches.

the structures retained when the whole deposit had hardened and the sands had become sandstones would be those originally devel-

oped in the clays and not those in the sands. In this way the impressions on the two sides of a sandstone mass would usually

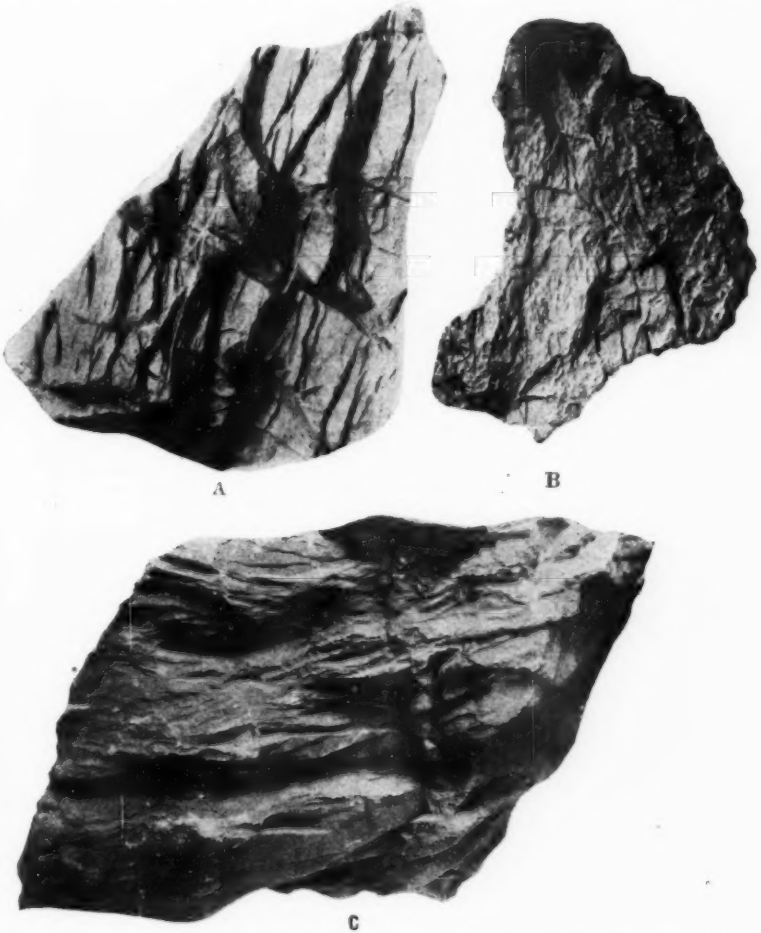


FIG. 2.—Photographs of "faulted and warped" sandstone blocks. From Sec. 36, T. 21 N., R. 11 E., Osage County, Oklahoma. Length of *B*, about 3 feet, *A* and *C* about 1 foot. Collected by Sidney Powers.

correspond approximately, but they would be unlikely to correspond in minor details and often they would be very dissimilar. The sandstone slabs with faults on only one side were evidently formed in a somewhat different manner. These can be explained only on the assumption that movements affected hardened muds so that the upper surface presented a series of small faults, and that later sands were spread over this surface. After final induration of the sands, faults scarps would mark the undersurface of the resulting sandstone slab, and the normal bedding-planes of the sands would be preserved.

The evidence is conclusive that these faultlike structures in the Pennsylvanian of northeastern Oklahoma were developed before the final consolidation of the sands into sandstones. The strand markings associated with the faults show that deposition took place on or near a shore, and the great southward thickening of the beds toward the source of abundant detrital material in the mountainous areas of the Arbuckles suggests that it proceeded at an unusually rapid rate. Under such conditions slumping and settling would occur and dislocations would develop in the beds involved. These facts and relationships lead to the conclusion that the minute step faults in sandstone masses interbedded with shales in this area are the impression of structures developed in partly indurated muds and are the result of slumping previous to the final consolidation of the muds and sands.

DISCUSSION

RAYMOND C. MOORE: Sandstones with features practically identical in all particulars with those described in this paper by Mr. Ross are common in the upper part of the Morrow and base of the Winslow formations, lower Pennsylvanian, in the vicinity of Fayetteville, Arkansas, and elsewhere.

GEOLOGICAL NOTES

DEVELOPMENTS AT FORT NORMAN, MACKENZIE DISTRICT, CANADA

Operations of the Imperial Oil Company along Mackenzie River have been summarized by the Geological Survey of Canada,[1] and Figure 1 from this *Bulletin*, Volume 5, page 526, is reproduced with the addition of new wells. The discovery well was completed in 1920 at a depth of 783 feet. After cleaning out in 1922 the well was deepened to 951 feet,

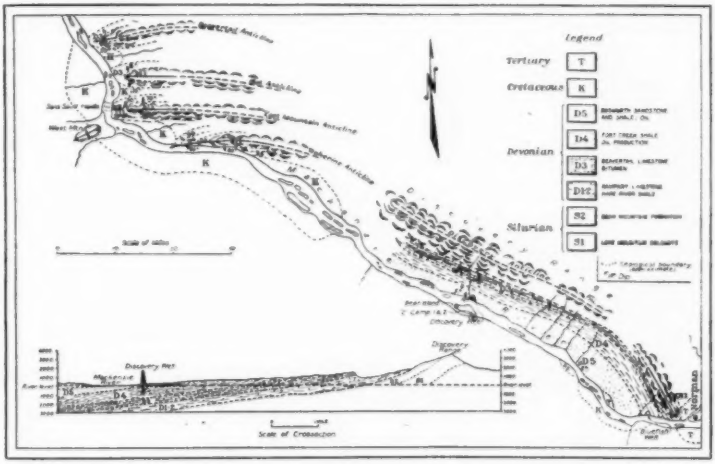


FIG. 1

and showed a possible daily production of 60 to 70 barrels. Four other wells have been drilled. The Mackenzie River Oil Company (Fort Norman Oil Company) drilled 8 miles south of the discovery well and on the same side of the river in 1921 to 1,510 feet, and obtained sufficient gas for heating purposes. The Imperial Oil Company drilled to a depth of 500 feet on Bluefish Creek, 8 miles west of Norman; on Bear Island,

[1] G. S. Hume, "Geology of the Norman Oil Fields and a Reconnaissance of a Part of Laird River," *Geological Survey of Canada, Summary Report*, 1922, Part B, 1923.

near the discovery well, to a depth of 2,304 feet; and at "C" camp south of Bear Island At the last locality the first well was lost at 1,705 feet, and a twin was drilled to 3,057 feet. No oil or gas in commercial quantities has been found except in the discovery well. A new well will probably be drilled near the discovery well this summer.

SOME NOTES ON TRIANGULATION TARGETS

There are many discussions of the principles of triangulation, but, as far as the writer is aware, little has been written of the various types of triangulation targets and their uses. The following paragraphs give brief descriptions and discussions of various types of these targets suitable to conditions in the Rocky Mountain region.

It is usually possible in an area which is to be mapped to use a few natural objects, such as points of rock, the tops of hills, mountains, etc. as triangulation targets. It is rarely possible, however, to find enough such objects to make the erection of other targets unnecessary. The advantages of natural objects as targets are permanency and the fact that they require no time for construction. There are some disadvantages in using such targets, the chief of which is that they rarely appear the same from all directions. Objects such as chimneys, windmills, buildings, etc., are more satisfactory and are much used. They cost nothing, usually appear the same from all directions, and are permanent, but often are not so located as to be visible for great distances from all directions.

Rock monuments are, probably, the most used type of triangulation target. Such targets, properly placed, can be seen for considerable distances and are permanent. The construction of rock monuments is a time consuming and laborious task, especially if they are built to a height of more than 4 or 5 feet. A monument cannot be seen for great distances except with the sky as background. This can be partially remedied by girdling the monument with white muslin. The plane table cannot be set up directly over the triangulation point when using monuments. If the monument is built to a height of more than 3 feet, and it is desirable to take observations in all directions, it is necessary to set up the plane table twice, or to make the set-up at a little distance from the monument. If the monument is on the top of a steep hill, neither procedure may be practicable. There is a greater likelihood of small errors in orientation when the table is set up near the monument than there is if the table is placed directly over the point. A monument should have a flat rather than a pointed top, because the flat top

is a much better object on which to set the horizontal hair of a telescope (Fig. 1.) At great distances the exact position of the top of a pointed monument cannot be made out, which leads to small errors in the vertical angles read. All that has been said of rock monuments is also true of sod monuments.

A staff with a flag nailed to it is a widely used type of triangulation target. This type of target is easily and quickly erected. If the staff is not set into the ground, a guy wire may be loosed, the staff and flag thrown aside, and the plane table set up directly over the point. When

FIG. 1.—Type of rock monument much used by geologists in the high plains and Rocky Mountains regions.

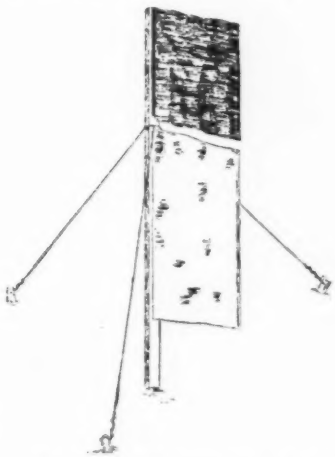


FIG. 2.—Satisfactory type of triangulation target which can be seen against any background.

only a white flag is used, this type of target is very hard to see against the sky. If white and black flags are both used on the staff, the target can usually be seen against any background (Fig. 2). The height of the staff and the size of the flags used in this type of target will be determined by the greatest distance from which observations are to be made. The staff is usually guyed with three wires, but in some cases, if the point is not to be occupied, the staff is solidly spiked to a fence post or any other convenient object. The usual practice is to fasten one of the short sides of a rectangle of cloth to the staff, which results in a streamer effect. In quiet weather the flag is hard to see and in windy weather

is likely to wrap around the staff if fastened on in this manner. It is more satisfactory to fasten the long side of the rectangle of cloth to the staff, because when attached in this manner the cloth stands farther away from the staff in quiet weather. The selvage edge of the cloth should be placed away from the staff, because this edge does not ravel when whipped about by the wind.

Trees make very good triangulation targets, especially when the lower branches are removed. The trunk, if straight, may be used in orienting the plane table, and the horizontal hair may be placed at the bottom of the branches when reading vertical angles. The wrath-provoking infrequency with which trees grow where they can be used as triangulation targets led the writer to cut them whenever they might be found and transfer them to the desired point. A symmetrical evergreen tree of the desired height is selected and trimmed within about 2 feet of the top. A length of white muslin is nailed to the trunk. The top of the muslin should be at the bottom of the branches and should extend a considerable distance down the trunk. The tree and flag are supported by three wires so placed as to prevent wrapping of the muslin around the trunk (Fig. 3). This target can be seen against any background, is inexpensive, and may be erected in a few minutes. When seen against the sky in any weather, the dark tree top stands out very clearly and the horizontal hair is set on the bottom of the branches when reading vertical angles. If seen against any other background, the white muslin flag can be seen easily and the horizontal hair is set on the top of the cloth. Since the bottom of the branches and the top of the cloth are the same point, no correction is necessary. Triangulation targets of the types just described may be seen for great distances. The writer has read angles to such targets at a distance of 87,000 feet, or more than 16 miles.

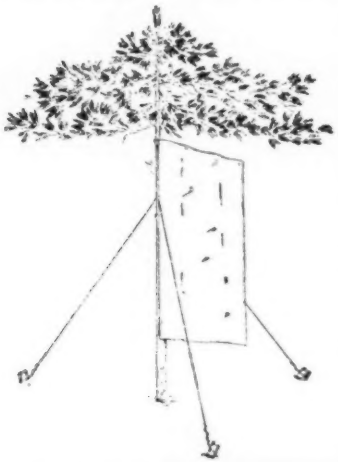


FIG. 3.—Ideal type of triangulation target. This target can be seen against any background and is visible under any wind condition.

ERNEST GUY ROBINSON

February 5, 1924

OCCURRENCES OF OIL AND GAS IN WYOMING

There are now sixty-five localities in the state of Wyoming where oil or gas in commercial, or near-commercial, quantities has been discovered. The principal product is gas in twenty-five and oil in forty localities. The most important source of oil and gas in the state is in the sands of the Frontier formation, in the Colorado group of the Cretaceous system. The occurrences of oil and gas, therefore, have been grouped around that formation in this summary. The twenty-five occurrences of gas may be divided as follows:

Above the Frontier formation	2
In the Frontier formation	12
Below the Frontier formation	11

The occurrences of oil in the state are more numerous in the lower part of the Upper Cretaceous, and in the Carboniferous beds, than in the Frontier formation, but neither the quantity nor value of the oil produced from these lower beds approaches that from the Frontier. The forty occurrences of oil may be divided geologically, as follows:

Above the Frontier formation	6
In the Frontier formation	7
In the Mowry formation	2
In the Dakota group (including the Muddy sand and Cloverly formation)	10
In the Jurassic, Triassic, and Carboniferous	15

From these figures it appears that when drilling upon an untested structure in Wyoming the chances are nearly two to one that if the Frontier sands are productive they will contain gas, and are more than two to one that the sands below the Frontier will yield oil instead of gas.

The character of the oil produced in Wyoming tends to grade from a high gravity, light-colored paraffin base oil in the Frontier and Mowry formations down to a low gravity, black, asphaltic oil in the Carboniferous formations. The range in Baume gravities, according to geological age, is as follows:

Oil occurring above the Frontier formation	31.6° Baume
In the Frontier formation	38.9° Baume
In the Mowry formation	42.0° Baume
In the Dakota group (including the Muddy sand and Cloverly formation)	36.6° Baume
In formations below the Cretaceous	22.9° Baume

E. L. ESTABROOK

January, 1924

THE JURASSIC AS A SOURCE OF OIL IN WESTERN CUBA

The occurrence of asphalt deposits in the western part of Cuba, notably at Mariel and Bejucal, is evidence that at one time oil accumulations were present below the surface. At Mariel it has been estimated that twenty to thirty million barrels of oil must have been oxidized to leave this residue. An igneous intrusion through the Cretaceous and younger sediments was the cause of the migration of the oil to the surface. At Bejucal the asphalt occurs in connection with fault fissures, but with no evidence of igneous intrusion.

Most of the wells which have been drilled in Cuba have been located in or at the contact of serpentine in regions of extreme distortion. Some produced high-grade oil for short periods, and the writers are informed that at present some twenty barrels of oil are produced daily from Bacuranao and Motembo in western Cuba. The oil at Bacuranao is of high gasoline content, while that at Motembo is almost naphtha.

Live oil seepages have been reported from various localities, but the writers have observed only one, about 2 miles northeast of the town of Madruga in Havana province.

Little has been published as to the origin of this oil. Some refer the probable source to the Jurassic, others to the Cretaceous, but few have made any effort definitely to connect the oil with a certain stratum or formation. As the oil-generating strata are of great importance in determining whether or not any future development may be expected in western Cuba, the writers have endeavored to connect the oil produced and evidenced with either the Jurassic or Cretaceous sediments.

A thorough examination of the literature and available private reports and a field study of Havana and Pinar del Rio provinces were made with this end in view. This investigation has led to the conclusion that the Jurassic limestones and shales are the most likely source of the oil, and that there should be valuable deposits yet to be found under favorable structural conditions in western Cuba. The reasons for this conclusion are: (1) The highly petroliferous character of these Jurassic sediments makes them stand out among the other sediments of Cuba as likely source beds. The non-oil-forming beds resting uncomformably on the Jurassic are impregnated with asphalt to a very great extent in Pinar del Rio province. In Havana province the oil seeps and asphalt deposits 3,000 or more feet above the Jurassic are found in connection with post-Jurassic faulting or igneous intrusions. (2) At Bacuranao and Madruga, fragments of what appears to be altered Jurassic limestone are found in later volcanics and contain liquid hydrocarbons.

STRATIGRAPHY OF WESTERN CUBA

The oldest rocks in Cuba are highly metamorphosed schists, slates, limestones, marbles, and granites. Various igneous rocks have been intruded at different times. Dr. Carlos de la Torre, of the University of Havana, has informed the writers that no Triassic has been identified, although some black altered limestones in the province of Santa Clara, near the town of Trinidad, may be of that age.

The Oxfordian, Kimmeridgian, and Portlandian of Middle and Upper Jurassic have been identified by Barnum Brown, Marjorie O'Connell, and Dr. de la Torre, and are the oldest sediments identified on the island. At Vinales these formations are well exposed, and their combined thickness is 2,000 feet or more. All are petroliferous and emit a distinct odor of petroleum when struck with the hammer.

The Oxfordian consists of thick strata of blue-black limestone and thin shales, with cavities and calcite seams containing residues of petroleum. This is a fossiliferous, marine formation containing ammonites, fishes, and reptiles.

The Kimmeridgian contains gray-black to black limestones with thick parting shales. Calcite veins cross the formation, and black concretions, frequently inclosing ammonites, are numerous.

The Portlandian is made up of hard gray and gray-black limestone, fossiliferous and thin-bedded at top with intercalated shales and occasional chalcedony lenses.

These three divisions appear to have been laid down under conditions favorable to the generation of petroleum, as is evidenced by their color and character.

The Jurassic beds of Cuba have been correlated by Barnum Brown and Marjorie O'Connell with those of Mexico. Burckhardt has described the Middle and Upper Jurassic of Mexico, and, according to Dr. de la Torre, who has inspected these sediments in both Mexico and Cuba, they are very similar lithologically and paleontologically, and are also bituminous. Professor A. W. Grabau has published a map correlating the Neo-Jurassic sea, which indicates that these beds underlie the entire oil-producing areas of Mexico, Colombia and Venezuela, and southwestern Texas. His map also includes the western part of Cuba.

The vast amounts of oil produced in Mexico indicate a great thickness of oil-generating strata, and the Upper and Middle Jurassic, estimated by Burckhardt to range from 400 to 1,700 meters, are considered by the writers as a much more likely origin than the Tamasopa, San Felipe, or Mendez formations. The Tamasopa, which is considered by many

to be the original source, has been observed in some localities entirely unattended by hydrocarbons. The San Felipe and Mendez shales as described do not compare with the Jurassic in petroliferous character. Again, all oil so far produced in Mexico has been associated with faulting or igneous intrusion, either of which may cause the upward migration of the oil from Jurassic rocks.

Lying unconformably upon the Jurassic is the Lower Cretaceous series of felspathic sands, sandy shales, and shales with occasional limestones. A conglomerate at the base varies in thickness, and in Pinar del Rio province represents continental deposition, while in Havana province it contains marine fossils and resembles a shore deposit. In Pinar del Rio it is impregnated with bitumens along the joints and in the interstices of the matrix. The fractured sands and shales near the base yield a foul odor when broken, and contain bitumens.

The Middle Cretaceous is represented by white marly shales in the lower phase, with open granular limestone grading into limestone conglomerate in the upper phase.

The Upper Cretaceous consists of thick arkosic conglomerate at the base succeeded above by felspathic sands and shales.

A series of limestones and shales recorded as "caving" or "rotten" in well logs is referred doubtfully to the Eocene. The Oligocene consists of hard crystalline limestones.

PROBABILITY OF COMMERCIAL OIL UNDER SUITABLE COVER

The search for commercial oil has not been well rewarded in Cuba. The question arises: Do the asphalt deposits represent all that remains of an oil supply that has leaked away, or does a considerable part remain? Let us postulate the conditions under which petroleum theoretically should occur in western Cuba, and then examine actual experience of drilling.

There are the highly bituminous Jurassic strata outcropping in Pinar del Rio province which apparently extend over the western part of Cuba. Unconformably upon the Jurassic lie the Lower Cretaceous shales, sands, and basal conglomerate. When there is a suitable structure, this Lower Cretaceous conglomerate might reasonably contain oil.

The only other porous beds with capping are the felspathic sands and conglomerate together with the underlying granular limestone of the Upper Cretaceous. Oil could reach these beds only in case of faulting, or fracturing caused by igneous intrusion, thus allowing the

oil to rise through the Lower Cretaceous shales. Shattering caused by igneous intrusion or folding of strata against igneous masses ought to open up favorable reservoirs.

Comparisons are unreliable, but in this connection it may be pointed out that in Mexico igneous plugs have been associated with fracturing and have influenced folding as in Cuba, and have formed reservoirs holding oil.

A reference to well logs shows that actually there have been two classes of wells drilled in Cuba: those beginning in the Tertiary or, in some cases, Cretaceous strata; and those in serpentine. None of the former have reached the Lower Cretaceous sands, and it is doubtful if any reached the Upper Cretaceous sands; and if so, not in a zone reached by oil migration from lower beds. In the second class are wells which have been drilled directly into serpentine. This class produces practically all the oil now found on the island. The serpentine is a poor container, being a mass of fractured, decomposed igneous rock without sufficient capping.

The writers believe that under suitable structure in the Lower Cretaceous so far not reached by the drill, oil will most likely be found in commercial quantities.

ALBERT WRIGHT, JR., AND P. W. K. SWEET

MADRUGA, CUBA

CARBON RATIOS OF CRETACEOUS COALS IN NEW MEXICO IN THEIR POSSIBLE RELATION TO OIL

The purpose of this paper is to present the results of a compilation of the carbon ratios (fixed carbon content) of coals in formations of Cretaceous age in New Mexico in an effort to interpret their possible relations to oil. Since there are, at present, only widely scattered oil fields in New Mexico, the relation of the carbon ratios of the Cretaceous coals to oil in Cretaceous sediments is, at best, a matter of conjecture. The theory of the relation between the carbon ratios of coal and petroleum deposits as developed by David White[1] and applied by Fuller[2] has been

[1] David White, "Some Relations in Origin between Coal and Petroleum," *Wash. Acad. Sci.*, Vol. 6, March 16, 1915.

[2] Myron L. Fuller, "Relation of Oil to Carbon Ratios of Pennsylvanian Coals in North Texas," *Econ. Geol.*, Vol. 14 (Nov., 1919), No. 7; "Carbon Ratios in Carboniferous Coals of Oklahoma and Their Relation to Petroleum," *ibid.*, Vol. 15 (April-May, 1920), No. 3.

found of considerable use in the prospective oil territory of Oklahoma and Texas. The degree of success of the theory applied depends to a large extent on the amount of data available. In a given region where the data are more or less widely separated, as in New Mexico, it seems permissible tentatively to extend the isocarbs between the separated points, providing the correlation is reasonable. Of course, in a region of few or no coal-bearing beds, the carbon ratio theory is of little use.

In prospecting a new region such as New Mexico for petroleum accumulations, all data bearing on oil possibilities should be investigated. A compilation of carbon ratio data of the coals of New Mexico should be of some use. It is not intended by the map or paper to recommend or condemn any areas in New Mexico for petroleum prospecting, but it is intended to call attention to the possible use of the carbon-ratio theory in future prospecting. In this paper the theory is applied only in reference to oil in the Cretaceous formations. The possibilities of oil in Pennsylvanian sediments are not considered.

The coal analyses used and noted on the map are those made by the United States Bureau of Mines in which the samples of coal were made free of moisture and ash, leaving the pure coal. It will be seen that the fixed carbon content of the Cretaceous coal deposits sampled does not go above 66 per cent, and most of the analyses shows a percentage below 50 per cent. By means of the isocarbs, the relative degrees of metamorphism to which the Cretaceous sediments have been subjected are shown. The isocarbs are necessarily general, due to scattered data, and in many cases they have been sketched in to show a possible interpretation of their position.

The isocarbs indicate a basin or geosyncline through parts of Rio Arriba, McKinley, Valencia, and Sandoval counties. Lacking data on additional coal deposits within the basin, the carbon ratios are presumed to be below 50 per cent. However, Lahee[1] suggests "there is another possibility in this region, namely, the presence of a number of scattered igneous intrusions which, locally, might easily have affected either the adjacent oil or adjacent coal . . . . ."

In the San Juan region in northwest New Mexico considerable "wildcatting" is in progress at present since the discovery of oil in the Midwest Refining Company's well in Sec. 19, T. 29 N., R. 16 W., San Juan County. The Producers and Refiners Corporation found a prolific gas horizon at 2,370 feet in their well in Sec. 1, T. 31 N., R. 14 W., in the same county and northeast of the Midwest well. The Midwest

[1] F. H. Lahee, personal communication.

Company drilled an offset to their discovery well and it proved a failure. This failure retarded somewhat pending negotiations for additional wells to be drilled by other parties. More recent discoveries, however, by

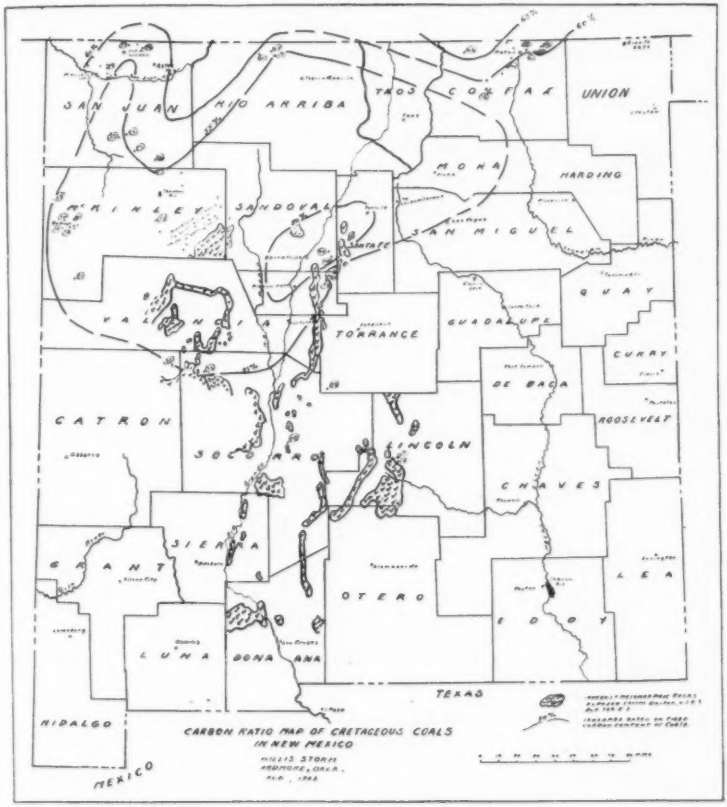


FIG. 1

the Midwest Company have shown the existence of a good commercial pool on the Hogback fold.

A general conclusion may be reached from the compiled data that the carbon ratios of the Cretaceous coals in New Mexico are not so high as to be prohibitive to oil and gas accumulation since the highest fixed

carbon content noted is 66 per cent. Using the table prepared by Fuller and included with this paper, the theory would predict grades of oil from the Cretaceous sediments, similar to the Mid-Continent fields. However, since the carbon ratios are thought to increase with depth,[1] it is not without reason to expect still lighter gravity oil in the Mesaverde formation where sufficiently buried. The high gravity

TABLE I

RELATION OF OIL AND GAS TO CARBON IN COAL
(AFTER FULLER*)

Carbon Ratios (Surface)	Prevailing Characteristics of Sands	Prevailing Water Conditions (in Mixed Formations)†	Production‡
Over 70.....	Hard and tight	Water usually absent except near surface	No oil or gas, with rare exceptions
65–70.....	Tight, with few porous spots	Water usually absent below 1,500 feet	Usually only "shows" or small pockets. No commercial production
60–65.....	Variable, with porous beds of limited extent	Water usually absent below 2,500 feet (often below 2,000 feet)	Commercial pools rare, but oil, exceptionally high grade when found. Gas wells common, but usually isolated rather than in pools
55–60.....	Fairly continuous and open	Water usually absent below 3,000 feet (often below 2,500 feet)	Principal fields of light oils and gas of the world
50–55.....	Softer, less firmly consolidated, and more continuous and porous	Water usually absent below 3,000–3,500 feet	Principal fields of medium oils of Ohio-Indiana and Mid-Continent fields
Under 50.....	Usually unconsolidated and porous throughout	Sands usually saturated, often with fresh water to all depths reached by wells	Fields of heavy Coastal Plain oils and of unconsolidated Tertiary or other formations

* Myron L. Fuller, "Relation of Oil to Carbon Ratios of Pennsylvanian Coals of North Texas," *Econ. Geol.*, Vol. 14 (Nov., 1919), No. 7.

† Unusually porous sands like the Dakota of the West and the St. Peter of the East carry water in quantities far above the average and to far greater depths and distances from the outcrops.

‡ Statements of quality apply to the oils from sandstones; oils from limestones are usually considerably heavier.

oil found in the Midwest well cannot be said to have any normal relation to the increasing carbon ratios with depth, for, as Lahee[2] suggests:

The Midwest structure which produces this oil has at least one fault in it which may have served as a channel for the migration of the oil or may have had some connection with the origin of oil of this light gravity.

He further points out:

The high Baumé-gravity of the oil found in the first Midwest well can hardly have any normal relation to the carbon ratio of coal in the vicinity.

[1] It was found in England that this was not the case. See E. L. Ickes, *1279 P.A.I.M.E.*, October, 1923.

[2] F. H. Lahee, personal communication.

High gravities of this kind generally suggest seepage upward from below, that is, the escape of some of the lighter consituents from a deeper lying accumulation of oil. I do not believe that in this instance this high gravity is due merely to a rapid increase in metamorphism with depth in the Cretaceous formation.

An additional fact to be considered in this light is the presence of large anticlines, synclines, and domes in the region which are the result of considerable orogenic movement during Cretaceous times.

It is hoped that this necessarily incomplete paper will shed some light on the petroleum possibilities of New Mexico from the standpoint of carbon ratios of known coal deposits. It is, however, a minor consideration and is of only regional use in the search for oil.

Acknowledgment is made for the helpful and constructive criticism of Mr. David White and Dr. F. H. Lahee.

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WILLIS STORM

ARDMORE, OKLA.
July, 1924

VOLCANIC ASH IN NORTHERN LOUISIANA

One of the far-reaching results of taking cores in the drilling of wildcat wells in Louisiana and Arkansas is the discovery of volcanic ash deposits. Mention has been made[1] of the discovery of bentonite in a well drilled by the Neighbors Oil and Gas Company in Sec. 19, T. 20 N., R. 6 E. Louisiana. The determination of this material was made by C. S. Ross, of the United States Geological Survey, under the direction of K. C. Heald. Since that time volcanic ash has been discovered in a number of other localities in Louisiana and Arkansas ranging in age from Lower Cretaceous to the Jackson formation of the Eocene. The greatest thickness of the material was found in a well drilled by the Palmer Corporation in Sec. 3, T. 18 N., R. 5 E., Ouachita Parish, Louisiana. The bit entered the volcanic ash at about the horizon of the main source of gas and continued, more or less unbroken, for about 1,200 feet. Comanchean Cretaceous fossils were found just below the volcanic ash.

A well, which is now being drilled by the Triangle Drilling Company in Section 5, T. 21 N., R. 5 W., found volcanic ash in what is probably the lower part of the Wilcox. There is still some doubt as to the presence of Midway in this general area. What the geologists and drillers of northern Louisiana and southern Arkansas have been calling "kaolin" or "chalk," near the contact between the Cretaceous and the Tertiary, may prove to be neither Midway nor Wilcox, but volcanic ash.

The upper part of the volcanic ash from the Triangle well contains numerous impurities including lignite. This impure phase grades down-

[1] H. D. Easton, *Oil Weekly* (February 16, 1924), p. 126.

ward into an almost pure white ash, which, under the microscope, contains small fragments of volcanic glass.

In a well now drilling in Sec. 10, T. 16 S., R. 14 W., Arkansas, volcanic ash has been found from 2,864 to 3,022 feet, cores from this horizon showing the material to be of a dirty burnt-red and green color very similar to much of the material from the Palmer Corporation well in the Monroe gas field. This is approximately at the horizon of the Woodbine sand or about 800 feet below the uppermost producing horizon of the old El Dorado field.

Two known volcanic ash outcrops, one in the Jackson formation and the other in the St. Maurice, have been discovered in Louisiana.

The widespead distribution of volcanic ash in Cretaecous and Tertiary formations of this region forms an interesting subject of speculation among local geologists as to its origin, and will probably prove to be of great economic importance as key-beds in working out subsurface structure.

Mr. H. D. Easton, of Shreveport, is getting together all the cores and specimens possible, and will prepare an exhibit and paper for the coming annual meeting of the American Association of Petroleum Geologists to be held in Wichita, Kansas, March, 1925. Any assistance given him by geologists in neighboring states, by sending in specimens of volcanic ash, will be appreciated.

A. F. CRIDER

SHREVEPORT, LA.
July 9, 1924

TEMPERATURE OF OKLAHOMA'S DEEPEST WELL[1]

Oklahoma's deepest well, 5,281 feet in depth, was drilled in 1923 and 1924 by the Kingwood Oil Company and the Cosden Oil and Gas Company. The well, which is known as the Boston Barnett No. 1 well, is in Sec. 7, T. 7 N., R. 10 E., about 6 miles east of Holdenville in Hughes County. It was drilled in search of oil, but a strong flow of water encountered at 5,281 feet caused drilling to be discontinued at that depth.

The well passed through Pennsylvanian and Mississippian strata from the surface to a depth of perhaps 4,683 feet, and then penetrated rocks of Devonian, Silurian, or older age.[2]

Through the interest and kindness of Mr. J. T. King, president of the Kingwood Oil Company, the writer measured the temperature of

[1] Published by permission of the Director of the United States Geological Survey.
[2] Letter from Frank C. Greene dated June 9, 1924.

the well on January 15 and 16, 1924, when it had reached a depth of 5,248 feet. Thermometers were provided by C. E. Van Orstrand, of the United States Geological Survey. The measurements, as they have been adjusted by Mr. Van Orstrand, are given in the accompanying table. The average rate of temperature increase diminished gradually with depth. From 100 to 3,000 feet it was 1° F. in 52.9 feet; from 100 to 4,000 feet, 1° F. in 51.9 feet; from 100 to 5,000 feet, 1° F. in 50.2 feet; and from 100 to 5,200 feet 1° F. in 49.9 feet, thus proving that the depth-temperature curve is slightly convex to the axis of depth. The rate of temperature increase is similar to that of other Oklahoma wells whose temperatures have been measured.[1]

TABLE I

TEMPERATURE MEASUREMENTS OF BOSTON BARNETT NO. 1 WELL, HUGHES COUNTY, OKLAHOMA

DEPTH IN FEET	OBSERVED TEMPERATURES IN DEGREES FAHR.	100–3,000 FT.		100–5,200 FT.		CONSTANTS
		Computed Temperatures	Observed Minus Computed Temperatures	Computed Temperatures	Observed Minus Computed Temperatures	
000.....	60.7	62.9	−2.2	61.4	−0.7	100–3,000 ft.
100.....	65.3	64.8	+0.5	63.4	+1.9	a=62.91
2,000.....	99.3	100.7	−1.4	101.4	−2.1	b=0.01891
3,000.....	120.6	119.7	+0.9	121.4	−0.8	$1/b$=52.9
4,000.....	140.2	138.6	+1.6	141.5	−1.3	
5,000.....	163.3	157.5	+5.8	161.5	+1.8	100–4,000 ft.
5,200.....	166.0	161.3	+4.7	165.5	+0.5	a=62.55
						b=0.01925
						$1/b$=51.9
						100–5,000 ft.
						a=61.51
						b=0.01994
						$1/b$=50.2
						100–5,200 ft.
						a=61.38
						b=0.02002
						$1/b$=49.9

The temperature (y) in degrees Fahrenheit at depth (x) in feet is given by the equation $y=a+bx$.

The constants are defined as follows: a=computed mean annual temperature expressed in degrees Fahrenheit; b=gradient expressed in degrees Fahrenheit per foot; $1/b$=reciprocal gradient expressed in feet per degree Fahrenheit.

HUGH D. MISER

[1] C. E. Van Orstrand, "Temperatures in Some Deep Wells in the United States," *Wash. Acad. Sci., Jour.*, Vol. 9 (1919), p. 382.

THE EFFECT OF PRESSURE ON THE MIGRATION OF OIL

At the University of Chicago, during the spring of 1924, Mr. Ira M. Hicks and the writer performed a few simple experiments to determine whether pressure alone would cause oil to migrate from clays into sands. The apparatus used consisted of an iron pipe 2½ inches in diameter and 28 inches long. One end of the pipe was closed with a screw cap, and the other end was fitted with a loosely sliding piston. About 1 inch from the end closed with the screw cap, a hole was bored through the pipe. This hole was ⅛ inch in diameter, and allowed the escape of air and water that might be displaced by the oil moving toward that end. At the piston end of the pipe, air or water could escape around the edge of the loosely fitting piston. In each experiment, about 8 inches of medium-grained sand was placed in the ends of the tube with about 12 inches of oil-soaked clay between. In the first experiments both ends of the tube carried either dry sand or water-soaked sand. Later it was ascertained that labor could be shortened by placing dry sand in one end of the tube and water-soaked sand in the other, with results that would show the effects of oil migration into the different porous layers under the same conditions of pressure and with similar oil content of the clay thus allowing more favorable comparisons. Under existing conditions it was not practical to determine the amount of pressure nor the amount of oil migrating from the clay to the sands. The results, therefore, are not in any sense quantitative.

Pressure was applied by means of a screw device that worked on the principle of an ordinary "jack screw." The pressure was maintained during twenty-two to twenty-four hours. In that time the oil migrated into the dry sand a distance of 5 inches (av.) and into the water-soaked sand 7 inches (av.): Furthermore, the oil traveled toward areas where there was the greatest release of pressure, viz., toward the small hole at the capped end of the tube and toward the edge of the loosely fitting piston. Thus the oil-soaked sand in the capped end of the tube formed an asymmetric cone with the base next to the clay and the apex toward the small hole in the side of the pipe. The oil-soaked sand in extending toward the circular edge of the piston permitted the formation of a cone of dry sand in that end of the tube. This cone of dry sand had the piston for a base with the apex of the cone pointing toward the middle of the tube.

These experiments show clearly that pressure is a factor in the migration of oil and that the migration takes place in a direction that gives maximum release of pressure.

To make sure that capillarity was a negligible factor in the migration of this oil, the same experiments were performed after placing about 2 inches of gravel about the size of a pea between the oil-soaked clay and the sands. Under these conditions, the results so closely approximate the results obtained without the gravel that the migration is known to be due solely to pressure in these experiments.

Further experiments in determining the effects of pressure on the migration of oil are under way, the results of which will be published later.

E. T. THOMAS

UNIVERSITY OF CHICAGO

REVIEW

Oil Shale, an Historical, Technical and Economic Study. By MARTIN J. GAVIN U. S. Bureau of Mines, Bulletin 210, 1922.

As indicated by the title, this bulletin is largely an assemblage of facts and ideas gathered from a great variety of sources. The author, quite logically, begins with a summary of the petroleum situation, for it is obvious that the development of an oil shale industry will depend upon the relation between the supply of and the demand for liquid fuels and other products petroleum. The oil shale deposits of foreign countries are briefly described (seven pages), and equal space given to the distribution and geology of those of the United States.

A considerable number of chemical analyses of oil shale are given as a part of the evidence bearing on "Nature and Origin" of oil-shales and the author discusses at length the probable composition of "kerogen" but concludes that "it is not probable that the kerogen of all shales has the same composition nor that the kerogen of any one shale is a definite chemical compound."

A considerable part of the text and numerous illustrations are devoted to a description of the oil shale industry of Scotland. This emphasis appears justifiable for it is in Scotland that the greatest advancement in the utilization of oil shale has been made. Systems of mining, mine ventilation, crushing, shale retorts, condensing systems, products of the industry, refinery practices, and plant costs are discussed.

The account of the history and status of the oil shale industry in the United States contains summary descriptions of a few early attempts to design and construct retorts, and lists some fifty different retorts or processes which have been proposed for use in the treatment of the oil shales of the United States.

Under the heading "Problems of an American Oil Shale Industry," the explosibility of oil shale, transportation and marketing of products, interrelation of retorting and refining, nitrogen recovery, plant location, disposal of spent or waste shale, and other factors in the growth of this new industry are discussed.

Near the end of the bulletin a few pages are given over to facts and figures about American oil shales and shale oils, analyses, results of experiments, etc.

This bulletin is excellently planned for the general reader. It will give him a carefully considered digest of what has been learned about oil shale, and particularly about the technology of oil shale. The volume is a little disappointing to those who have given much time and thought to this budding industry and its problems, for few new facts are given regarding the composition of the various American oil shales, their behavior under different methods of treatment, and the value of their products. Doubtless answers to many of the questions which are vital to the oil shale industry and which were not considered in this volume would have been available had not the appropriations made available for research by the United States Congress during the past few years been so niggardly.

DEAN E. WINCHESTER

THE ASSOCIATION ROUND TABLE

NEXT ANNUAL MEETING IN WICHITA, KANSAS

The Executive Committee has named Wichita, Kansas, as the place for holding the next annual meeting of the Association, and after conference with Marvin Lee, president of the Wichita Geological Society, has fixed the dates on Thursday, Friday, and Saturday—March 26, 27, and 28, 1925. Members domiciled in Wichita have shown great activity in expressing their desires for the meeting, and assure the membership that they have the facilities for staging a successful meeting in every way, including ample hotel accommodations, assembly-room, and entertainment features. The fact that the Association has never held a meeting in Kansas was another determining factor in the selection of Wichita. It is also conveniently accessible to a large percentage of the total membership. Kansas is also supplying considerable oil development of current interest in a number of separate districts, thus bringing up new problems in the petroleum geology of the state.

Dr. Decker states that he has never before witnessed so many good papers in prospect so early in the year, and by the time the annual meeting comes up the chances are we will find a very full, interesting, and varied program. The program itself, so far as papers are concerned, will be assembled, arranged, and printed at the secretary's office in Norman. All authors are requested to communicate directly with Dr. Decker, and to be prepared to furnish a brief abstract of their papers in advance of the meeting. Forms for this purpose will be mailed to each author, and it is absolutely essential that they be filled out in order that they may be printed with the program.

It is believed that the meeting will be characterized by a number of contributions in the field of research, and undoubtedly a great deal can be accomplished along this line by individual effort on particular theses wherein chemistry, physics, and paleontology are related to our problems. The association is becoming more and more one of scientific and educational standing as well as being utilitarian and economic in its relation to the petroleum industry. This is a happy situation that should be fostered.

Everything considered, the Wichita meeting shows prospects of being one consistent with the growth and usefulness of the association.

JAMES H. GARDNER

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This publication does not constitute an election, but places the names before the membership at large.

In case any member has information bearing on the qualifications of these applicants, please send it promptly to Charles E. Decker, Norman, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

FOR FULL MEMBERSHIP

Kenneth Aid, Eastland, Texas
Frederic H. Lahee, E. M. Closuit, David Donoghue
Fred W. Bartlett, Tulsa, Oklahoma
Karl H. Schilling, Robert J. Davis, T. K. Harnsberger
Roderic Crandall, Port Washington, Long Island, New York
Chester Naramore, William B. Heroy, Edwin B. Hopkins
George M. Cunningham, Berkeley, California
W. A. English, S. H. Gester, G. C. Gester
Josef T. Erb, The Hague, Holland
E. DeGolyer, Sidney Powers, T. K. Harnsberger
Donald D. Hughes, San Francisco, California
R. E. Collom, Carl H. Beal, S. Weidman
Francis W. Lake, Brea, California
Robert W. Phelps, William S. W. Kew, Walter A. English
John M. Vetter, Houston, Texas
Elfred Beck, E. F. Schramm, Erwin H. Barbour
Anselm Windhausen, Buenos Aires, Argentine
Stanley C. Herold, W. E. Wrather, Sidney Powers

FOR ASSOCIATE MEMBERSHIP

Thomas H. Allan, Denver, Colorado
Charles M. Rath, H. T. Morley, Charles T. Lupton
Donald M. Allen, Tulsa, Oklahoma
F. W. Floyd, C. D. Stephenson, J. V. Howell
Ivan V. Bentz, Fairfield, Nebraska
E. F. Schramm, Erwin H. Barbour, F. K. Foster
Ernest W. Brucks, Luling, Texas
David Donoghue, John R. Suman, Alexander Deussen
Ronald W. Byram, Austin, Texas
Hal P. Bybee, F. L. Whitney, L. T. Barrow
Tom L. Coleman, Ardmore, Oklahoma
Charles E. Clowe, R. A. Birk, H. C. George
Harold P. Larkin, Bartlesville, Oklahoma
M. J. Kirwan, T. E. Swigart, H. T. Beckwith
Charles D. Vertrees, Tampico, Mexico
John R. Suman, Paul L. Applin, W. F. Bowman
John D. Waring, Jr., Fort Worth, Texas
A. M. Hagan, Robert S. Burg, H. H. Adams

Walter G. Watkins, Marland, Oklahoma
Roswell H. Johnson, L. G. Huntley, R. E. Somers
Albert G. Wolf, Gulf, Texas
Alexander Deussen, Wallace E. Pratt, Dave P. Carlton

CALIFORNIA MEN ACTIVE

The spirit of co-operation, fellowship, and good will is being manifested among our members on the Pacific Coast. Vice-President E. G. Gaylord and Regional Director F. S. Hudson have initiated organization meetings in both San Francisco and Los Angeles looking forward to bringing the California men into closer contact with one another and with the American Association. The following letter mailed out in July is self-explanatory, and undoubtedly a great deal in the way of wholesome results will come out of their society. We will hear more from them next March at Wichita not only by participation in the program by elaboration on their papers rendered at the Los Angeles meeting in September but also from their application for a regional section. The constitution provides for the establishment of regional sections by a vote of two-thirds of the members in attendance at any regular annual meeting (Article 8).

JAMES H. GARDNER

To the California Members of the
American Association of Petroleum Geologists:

Many of the California members of the Association have believed for some time that Pacific Coast petroleum geologists need a more intimate meeting ground than that afforded by the national conventions of the Association such as that held in Los Angeles last October. There are now over one hundred members of the Association living and working in California. Many problems are continually arising which could be advantageously solved by closer and more frequent discussions between the petroleum geologists of California.

Such procedure would bring a twofold benefit: It would help the California members of the Association and also, by publication of papers, the Association as a whole.

Influenced by these considerations, meetings of local members of the Association have been held at San Francisco and Los Angeles, with the object of deciding on the advisability of forming a California Association of Petroleum Geologists to be composed of members of the Association. In brief, the decisions made at these meetings were as follows:

1. That we form a California Association of the members of the American Association of Petroleum Geologists, with the object of becoming a local section of that Association.

2. That a meeting of the California members of the Association be held in Los Angeles on September 26 and 27, 1924, in order to effect the organization of the "California Association" and for the further purpose of presentation and discussion of papers on subjects of geologic and petroleum-technologic interest.

3. That a committee be appointed to arrange for said meeting and to prepare a brief set of by-laws, designed so as not to conflict with those of the American Association of Petroleum Geologists.

The following have been appointed as members of the said arrangements committee: R. E. Collom, S. H. Gester, J. A. Taff—San Francisco; C. R. McCollum, R. B. Moran, E. D. Nolan—Los Angeles.

To make the meeting successful we must have good papers. It takes time to write a paper, therefore start now and submit title of your proposed paper to any member of the foregoing committee, E. G. Gaylord or F. S. Hudson.

Bear in mind—there are two ideas for the fall meeting: (1) to organize a California Association and ask for the establishment of a regional section from the American Association, and (2) to have a technical program presented by California petroleum geologists.

Sincerely yours,

THE ARRANGEMENTS COMMITTEE

OBITUARY

DR. HANS VON HÖFER

Dr. Hans von Höfer, one of the most eminent European petroleum geologists, died at his home in Vienna, Austria, February 9, 1924.

In the year 1876 Höfer visited America during the first international exhibition as observer for the Austrian government, with special instruction to investigate the new and rapidly growing oil development. The report entitled *Petroleum Industrie Nordamerika's* was published in 1877. Shortly afterward the American Institute of Mining Engineers conferred upon him its honorary membership, which Höfer valued very highly. Since 1876 Höfer has not been in America but he kept in touch with oil affairs through correspondence with his old friend, Captain Anthony Lucas, discoverer of Spíndle Top, and by diligent reading of American publications pertaining to the geology of oil.

For a great number of years Höfer taught geology at the Academy of Mines, Leoben, Styria, being highly esteemed by students and faculty. The Polish fraternity Czytelnia made him its honorary member, which is best evidence that narrow politics never entered his broad mind. The Austrian government made him Hofrat (counselor of the imperial court), elevated him to the nobility with the *praenomen* Edler von Heimhalt and the school he taught bestowed upon Professor von Höfer the title Doctor Rerum Montanarum Honoris Causa.

The international geological congress held in Brussels, Belgium, 1922, excluded Austrian and German geologists from participation, which Höfer deeply deplored, as, in his opinion, the science should not be bound by geographical and political boundaries. While suffering from the effects of the first attack of bronchitis, a few months before his death, von Höfer was invited to the September meeting of the American Association of Petroleum Geologists at Los Angeles. The eighty-year-old scientist appreciated this invitation and sincerely regretted that conditions prevented him from obtaining first-hand information about the progress of petroleum geology, of which, undoubtedly, he was one of the founders.

Shortly before word of his death was received in this country he was elected an honorary member of the American Association of Petroleum Geologists, the chief recognition which the association can bestow. It is with keenest regret that American petroleum geologists have learned of Dr. Höfer's death.

ADAM WRÓBLEWSKI

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

J. P. SMOOTS of the North Central Texas Company returned to Shreveport in May after a business trip to Colorado and other parts of the Rocky Mountain area.

W. L. GOLDSTON has recovered from an automobile accident that occurred between Fort Worth and Dallas in April. Mr. Goldston was in Shreveport, Louisiana, in May, looking after the interests of Frankel Brothers in Union Parish, Louisiana.

W. E. HOPPER, consulting geologist, 311 Edwards Street, Shreveport, Louisiana, is geologist for the Bethany Oil and Gas Company, operating in the Bethany gas field, and has an office in the Southwestern Gas and Electric Company Building, Shreveport.

DONALD F. MACDONALD, on furlough from his office of chief geologist with the Sinclair Oil Company, is temporarily located at Shreveport. He is making investigations in surrounding territory in Louisiana, Arkansas, and Texas.

W. Z. MILLER, whose office is in the Kennedy Building, Tulsa, Oklahoma, was recently in Shreveport, Louisiana, in connection with his recent work in East Texas.

ANGUS MCLEOD, chief geologist of the Roxana Petroleum Corporation in the Mississippi Embayment district, has moved his office from Shreveport, Louisiana, to the Simpson-Whiteman Building, Dallas, Texas, where W. VAN H. PELLEKAAN, chief geologist for the Shell interests in the United States, has his headquarters. The Shreveport office is now in charge of C. C. CLARK, resident geologist.

W. J. NOLTE has resigned his position in charge of the geological and engineering departments of the Palmer Corporation at Shreveport, Louisiana, and has accepted a position in the geological department of the Marland Oil Company of Texas at Wichita Falls, Texas.

ORVAL L. BRACE has charge of the geological work of the Marland Oil Company in Louisiana, with headquarters at 523 Wichita Street, Shreveport, Louisiana.

HOWARD N. SPOFFORD is geologist in charge of the Texarkana office of the Marland Oil Company, operating in Arkansas.

HENRY V. HOWE, head of the department of geology at Louisiana State University, Baton Rouge, started in June with a field class of five students to spend six weeks in the Arbuckle Mountain area of Oklahoma, and in parts of Arkansas and Louisiana. Professor Howe has just completed the spring term of a lecture course of university extension work in graduate geology at Shreveport, Louisiana, established in co-operation with the Shreveport section of the Southwestern Geological Society.

The Shreveport section of the Southwestern Geological Society, A. F. CRIDER, chairman, together with the Louisiana State University extension class in graduate geology at Shreveport, H. V. HOWE, lecturer, took its second annual field trip along the Eocene–Upper Cretaceous contact in southwestern Arkansas and northeastern Texas, June 13–15. Twenty-four geologists made up the automobile party starting from Shreveport, Louisiana, and working out of Hope, Arkansas, and Texarkana, Texas. Representatives were present from Louisiana State University, the University of Arkansas, the United States Geological Survey, and oil companies in Louisiana, Arkansas, Texas, and Oklahoma. The object of this field observation and the subsequent microscopic work is to determine the presence or absence of the Midway Eocene at the outcrop. The trip was arranged by a committee consisting of W. E. HOPPER, J. P. D. HULL, and W. C. SPOONER.

PHIL B. DOLMAN, geologist, associated with the Carter Oil Company for the past six years, has resigned to enter private practice. Mr. Dolman will make a tour of the Coastal and Western oil fields before opening an office in Tulsa.

JOHN K. KNOX, who recently served for two or three years as geologist for the Whitehall Corporation in India, and more recently has been in consulting work at Houston, has opened offices as consulting geologist in the Patterson Building in Denver, Colorado.

CARY P. BUTCHER is now working in the geological department of the Mutual Oil Company at 528 Patterson Building, Denver, Colorado.

HEATH M. ROBINSON has opened an office in Dallas, at 304 American Exchange Bank Building.

FRANK E. LEWIS, of Winfield, Kansas, is doing geological work for several months in Italy.

CHARLES M. GOULD has been appointed director of the Oklahoma Geological Survey at Norman, Oklahoma, beginning July 1, 1924.

MAX W. BALL, who is a member of the Board of Trustees of the Colorado School of Mines, has been active in establishing a professorship in oil-shale mining and refining at the School of Mines. Barnabas Bryan, of New York, has been secured to head this department.

C. MAX BAUER and C. H. WEGEMANN, of the Midwest Refining Company, are responsible for the location of the successful wildcat test at Fig Lake, Montana, 32 miles west of Billings, in Sec. 26, T. 1 N., R. 21 E. The well is reported to have a settled production of about 500 barrels per day from a depth of 3,825 feet. The oil has a gravity of 46° and a paraffin base. The producing horizon is reported as Dakota sandstone.

J. W. BEEDE is now geologist for the Dixie Oil Company, his home address being 210 King William Street, San Antonio, Texas.

A. E. HARTMAN, consulting geologist, has moved from Fort Worth to San Antonio, and has opened offices at 412 Travis Building.

J. O. NELSON, until recently with the Arkansas Fuel Oil Company, has accepted a position as geologist with A. F. Crider, who has charge of the geological department of the Dixie Oil Company at Shreveport, Louisiana.

ROBERT B. CAMPBELL, geologist with the Humble Oil and Refining Company of Houston, Texas, has returned from a year's postgraduate work at the University of Chicago. Mr. Campbell has been making a study of microscopic fossils and is particularly interested in the value of fish otolites, or "ear-stones," for correlative purposes.

DABNEY E. PETTY, of San Antonio, Texas, has recently been added to the faculty of the University of Texas as associate geologist in the Bureau of Economic Geology and Technology, succeeding T. L. Bailey, who will be absent on leave next year in the University of California.

JACK M. SICKLER is assisting J. M. Douglas in the Rocky Mountain region for the Union Oil Company of California.

J. TANIGUCHI, petroleum engineer for the Nippon Oil Company of Tokio, Japan, writes that Tokio and vicinity are recovering rapidly from the effects of the great earthquake of last September. Another earthquake shock was experienced late in June, but this was not severe.

EGGLESTON SMITH has opened offices at 5849–A, Grand Central Terminal, New York City. He has just completed tests at Oil City, Pennsylvania, on a new core-taking device operating with cable tools, and it is reported that a core was successfully secured from hard sandstone a great deal more rapidly than the formation would commonly be penetrated with cable tools. Further details will be awaited with interest.

The Tampico geologists enjoy luncheons and geological discussions in the same fashion as in many of the oil centers of the United States. On July 2, DR. J. J. GALLOWAY, of Columbia University, talked on the use of foraminifera in determining the age of geologic formations. At the meeting on July 16, MR. OGARRIO gave a very interesting talk on the general conditions of the Venezuelan oil fields, and PAUL WEAVER led an informal discussion of the

spacing of wells in the Mexican fields. Among those present were E. A. McKenna, M. P. White, S. R. Saye, M. B. Schnitton, S. W. Lowman, J. J. Galloway, of the International; Walt M. Small, J. B. Dorr, E. B. Stiles, of the Agwi; Theodore Chapin, H. F. Nash, J. A. Hendricks, D. D. Sparks, of the Empire; George A. Elledge, R. G. Reese, of the Mexican Sinclair; Rolf Engleman, of the Metropolitan; W. A. Baker, Jr., of the Transcontinental Petroleum Company; A. W. Noble, D. R. Semmes, G. F. Kaufman, W. S. Adkins, Paul Weaver, C. S. Adams, of the Aguila; P. H. Bohart, S. A. Grogan, A. H. Armstrong, G. H. Shelton, of the Mexican Gulf; Charles L. Baker, of the East Coast; Carroll V. Sidwell, D. A. Powell, of the Cortez; and Waldo Sheldon, of Sheldon & Burden, S. en C. R. Ogarrio, manager of Texas Company's Venezuelan operations, P. S. Armstrong, of the Mexican Gulf Oil Company, Thomas Gallahan, of the International Petroleum Company, visitors.

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